BIJU PATNAIK INSTITUTE OF IT & MANAGEMENT STUDIES, BHUBANESWAR

MANAGEMENT OF MANUFACTURING SYSTEM (MMS)

(4th SEMESTER –MBA-OPERATION SPECIALIZATION-BATCH-2021)

By

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18MBA 401 D

MANAGEMENT OF MANUFACTURING SYSTEM (MMS)

Credit: 3, Class Hours: 30-35

COURSE OBJECTIVES

- To make the students to understand underlying concepts of general manufacturing systems
- To provide more insights on cellular manufacturing systems
- To expose the students in to Just–in–Time conceptual ideas and familiar about the same
- To provide knowledge on synchronizing and Flexible manufacturing systems

Module – I : Manufacturing systems – Types and Process mapping –Manufacturing Process Planning – Definition, Scope and Elements –Manufacturing concept planning – Requirements of good manufacturing and assembly lines –Layout planning and analysis, Cellular manufacturing systems (Group Technology) – Cellular manufacturing formation –Cell formation –Methods and production flow analysis & minimization of inter-cell movement.

Module – II : Just–in–time systems – Overview, Principles and Benefits – Seven Wastes – Elements of JIT – Design and Improvement aspects of JIT – Kanban systems–Definition and Principles – Types of Kanban Single card and Two card Kanban – Push and Pull Concepts of Kanban – Constant Work–in–Process (CONWIP) – Concept and comparison with Kanban system

Module – III : Synchronous manufacturing (Theory of Constraints) – Definition, Operation planning and control based on theory of constraints – Measures of Performance – Constraints in manufacturing system – Drum–Buffer–Rope (DBR) Methodology – Flexible manufacturing systems (FMS) –Meaning, Components and types – Conceptual model of FMS – Applications of FMS, Machine loading and scheduling.

Reference Text Books:

1) Shahrukh A. Irani, Handbook of Cellular Manufacturing Systems, John Wiley and Sons Inc., 1999.
2) T.C. Cheng, S. Podolsky, Just–in–Time Manufacturing: An introduction, Second edition, Chapman and Hall Publications, 1996
3) Mahadevan B., Operations Management Theory and Practice, Pearson Publication, 3rd Edition, 2015
4) R. Panneerselvam, Production & operations management, Prentice Hall India private limited, 2017.
5) Aswathappa, K.,ShridharaBhat, K., Production and Operations Management , Himalaya Publishing House, 2014

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Module – 1

Manufacturing Systems

What is Manufacturing?

i. Manufacturing is derived from latin word "**menu factus**" which means made by hand.
ii. The process of converting raw materials, components or parts into finished goods that meet a customer's expectation or specifications.
iii. Manufacturing is the making of goods by hand or by machine that upon completion the business sells to a customer.
iv. Manufacturing in the transformation materials in goods or products.
v. Manufacturing is to plan and deploy an optimum way of transformation of material into goods by integrating people , capital, process system and enterprises to deliver product of value to the society.
vi. Manufacturing is value added process where direct and indirect values are associated to produce finished goods or products.

Figure: Manufacturing

Manufacturing and Production are often used as same terms but there is a big difference between them. Manufacturing is the process to convert raw material to a ready to sale finished product that is tangible. The manufactured product can be directly sold to end customer. Manufacturing involves many processes to convert procured raw material to a finished product. Almost all the processes add value to material but also consume some material for adding value. A lot of planning goes into this. Mostly men, machine and material is required as resource.

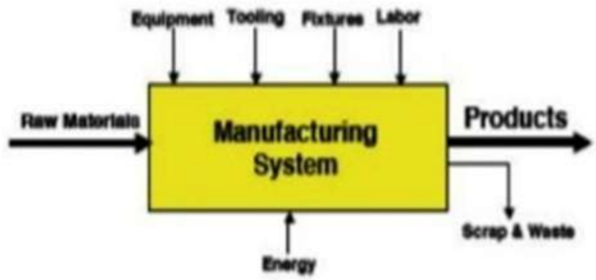
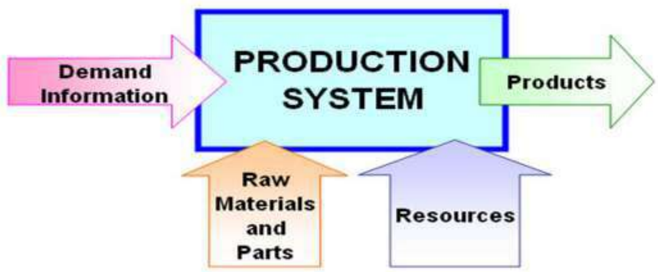


Figure: Manufacturing System

On the other hand, Production is process to convert any type of inputs to output, tangible or intangible. Mainly Production is creation of utility. Utility includes both goods and services. Productivity is measure of production that is defined as following way:



Difference between Manufacturing and Production

BASIS FOR COMPARISON	MANUFACTURING	PRODUCTION
Meaning	The process of producing merchandise by using resources like labor, machines, tools, raw materials, chemicals and others is known as a Manufacturing.	Production is a process of making something used for consumption by combining various resources.
Concept	A process in which raw material is used to generate output.	A process of converting inputs into outputs.
Compulsory resources	Men and Machine	Men
Form of input	Tangible	Tangible and Intangible
Form of Output	Goods only	Goods and Services
Creation of	Goods that are suitable for use	Utility

Types and Process Mapping:

Type of Manufacturing Systems:

Manufacturing entails so many processes and operations that comprehending them requires some type of categorization. Manufacturing operations can be categorized in several ways depending on the purpose of grouping, for example, national versus international or product types. For most purposes, classifications reflect the following six criteria:

1) Continuous or discrete
2) Variety and volume
3) Raw material to final product
4) To order or to stock
5) Size
6) Machinery used

Continuous or Discrete Manufacturing:

i. Manufacturing operations fall into two very broad groups: (a) continuous-flow or process type and (b) discrete-parts manufacturing (also known as discrete manufacturing). Continuous-flow operations typify the chemical and mining industries and oil refineries, which produce large amounts of bulk material. Products in these groups are usually measured in units of volume or weight, batch size is large, and product variety is low.

ii. Continuous-flow operations, used to manufacture "mature" products in large volumes, are relatively easier to control and operate, since production uses dedicated machines. These operations are usually fully automated, with operators minding the machines.

iii. The term discrete-parts manufacturing denotes operations involving products that can be counted. The output of process-type industries is also counted eventually: for example, sugar in terms of number of sacks or tons.

iv. A special feature of discrete manufacturing is that the end product, generally made of several components, can be disassembled and reassembled; an example is a bicycle. It is not essential for the end product to comprise several components. For example, a discrete manufacturing facility that machines only connecting rods of different shapes and sizes for automobile manufacturers produces a single-part end product.

Variety and Volume:

i. Another way to look at manufacturing facilities is according to variety and volume. A low-variety, high-volume operation is easier to manage, since dedicated automation is possible.

ii. A high-variety, low-volume operation, on the other hand, is more difficult to operate and manage. Based on volume and variety, discrete manufacturing is of three types:
   - Mass production
   - Batch production
   - Job shop

Mass Production:

i. In mass production of discrete parts or assemblies-for example, bolts or ballpoint pens-the production volume is high. Therefore, special purpose, dedicated equipment can be employed. Machines are considered dedicated when they are tailored to specific products.

ii. Examples of mass-produced goods include bicycles, washing machines, and video games.

iii. A mass-production facility is termed a transfer line when products are assembled while conveyor systems transfer them from one end of the plant to the other. A good example of a transfer line is an automobile-production facility.

Batch Production:

i. In batch production of parts or assemblies, the volume is lower, and the variety higher, than in mass production. When the end item is an assembled product, the producer may make some parts in house and buy others from vendors.

ii. Batch production is sometimes referred to as a midvolume, midvariety operation. The limited volume does not justify very specialized production machines; general-purpose machines are used instead.

iii. In batch production, goods are manufactured in batches that may be repeated as required.

Job Shop Production:

i. The job shop represents the most versatile production facility. Within the limitations of the machines and the operators, it can manufacture almost any product. With a low production volume, sometimes as low as 1 to 10 units, the cost of product design and set up is relatively high.

ii. Production facilities for aircraft, ships, or special machine tools are examples of job shops.

iii. NC and CNC technologies can significantly improve the productivity of job shops. Which of the three discrete-manufacturing facilities is suitable for a product depends on two factors: variety and volume.

iv. On the basis of volume and variety, the three types of manufacturing facilities just discussed can be represented graphically as shown in Figure. The overlaps emphasize the fact that their boundaries are not rigid. The actual values on the volume and variety axes depend on the complexity of the product.

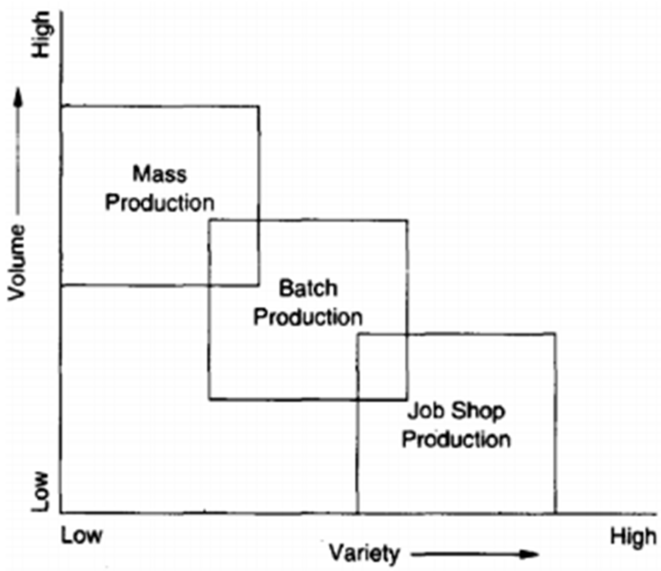


Figure: Volume and variety by production type

Raw Material to Final Product:

On the basis of the relationship between raw material and the end product, manufacturing follows one of four different patterns: disjunctive, sequential locational, or combinative.

i. ***Disjunctive:*** In the disjunctive pattern, a single raw material is progressively processed into its various components as end products. Examples of disjunctive facilities are slaughterhouses, lumber mills, and oil refineries.

ii. ***Sequential:*** In sequential facilities, too, there is only one raw material as input. But, unlike disjunctive operations, which separate the raw material into components, it is progressively modified to become the end product. An example is a supplier's production facility that machines castings for the automobile manufacturer.

iii. ***Locational:*** Locational patterns involve buying, storing, and eventually distributing manufactured goods without any substantial physical modification in the product. An example is the company that buys a product in large quantities and distributes it in small packets under its own brand name. This pattern suits bulk materials, such as sugar or rice.

iv. ***Combinative:*** The combinative type is basically discrete manufacturing in which components-some produced in-house and some bought from suppliers-are assembled, inspected, packaged, and shipped as end products. A good example is an automobile factory.

To Order or to Stock:

i. Based on the immediate destination of the end products, manufacturing may be of two types. In the first, products are shipped directly to consumers, wholesalers, or retailers. Such companies are said to produce "to order." Since they do not store the end products, for finished-goods inventory is unnecessary. Capital is therefore released and profit realized immediately following production. Job shops usually operate in this mode.

ii. In the second type, products are stocked in finished-goods inventory; marketing distributes them to retailers or consumers as needed. This type of operation is said to produce "to stock." Such facilities usually produce in batch sizes that minimize the unit cost. In this type, capital is tied up until the end products can be sold.

iii. To-order companies can respond rapidly to meet the needs of consumers, while to-stock companies can produce economically in smaller batch sizes, thus lowering thc capital investment in finished-goods inventory.

Size:

i. It is sometimes convenient to classify manufacturing companies on the basis of size, with criteria such as number of employees, annual sales turnover, net worth, and so forth. Whether a company is small or large is often determined by the number of employees.

ii. While there is no standard cut-off number, the following categorization is usually practiced: small, below 100; medium, 100 to 499; large, 500 or more.

iii. Contrary to the general perception that only large companies can afford modern facilities, the level of modernization and the sophistication of technology used are independent of the company size.

Machinery Used:

A variety of machine tools, equipment, and processes are used in an average plant. They fall into the following functional groupings:

- Metal forming
- Metal cutting

- Assembly
- Material handling
- Inspection, testing, gauging
- Others, such as casting, welding, riveting, brazing, heat treatment, washing stations, plastic molding, etc.

Types Manufacturing Processes:

Manufacturing processes are the primary processes and can be grouped under three basic categories, namely forming, machining and assembly. The objective of each process is to change the shape or physical characteristics of the raw materials.

1) **Machining processes:** Involve basically metal removal, by turning, drilling, milling, grinding, shaping, boring etc., it also includes chip less machining processes such as electro discharge machining (EMD), electrochemical machining(ECM), chemical milling, laser drilling etc.

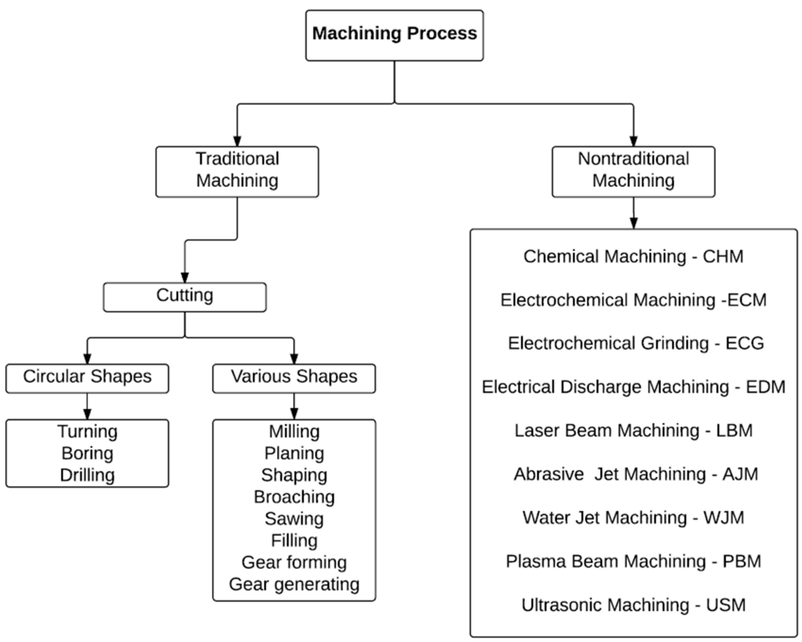


Figure: Types of Machining Process

2) **Assembly processes:** Involve the joining of component or piece parts to produce a single component that has a specific function. Some of the common assembly processes are welding, brazing, soldering, riveting, fastening with bolts and nuts and joining by use of adhesives.

Figure: Computer Assembly Process

3) **Forming processes:** Include casting forging, stamping embossing, spinning etc. these processes change the shape of the work piece without necessarily removing or adding material.

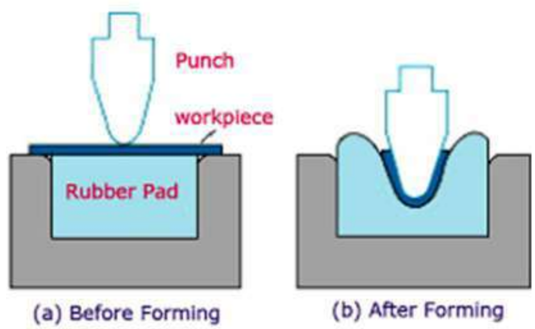


Figure: Forming of Sheet Metal

<u>Selection of a Process:</u>

The selection of a manufacturing process is influenced by several factors such as the desired product quality, labor cost to be achieved and the volume of production needed. While there can be several manufacturing methods or processes to produce an item, there is usually one best method for a given set of variables. Some of the common manufacturing processes are briefly described in the following paragraphs.

Forming Processes:

1) **Casting:** The casting process consists of pouring of molten metal into a mould and allowing sufficient time for the metal to solidify and retain the shape of the molded cavity. The various casting methods are sand casting, shell molding, gravity die casting, pressure die casting centrifugal casting, investment casting etc. Casting of plastics is done by compression molding, injection molding, transfer molding extrusion, vacuum forming and blowing.

2) **Embossing and Coining:** In embossing the metal is stretched or formed as per the configuration in the dies. Coining is performed in an enclosed die and the metal flow is restricted in a lateral direction. An impact or compressive force causes the metal to flow in the shallow configurations of the blank being coined.

Figure: Embossing Process

Figure: Coining Process

3) **Extrusion:** Extrusion process consists of forcing the metal through dies so that the metal obtains cross section of the same shape as the die. Extrusion process can be direct or forward extrusion, inverted or backward extrusion and impact extrusion.

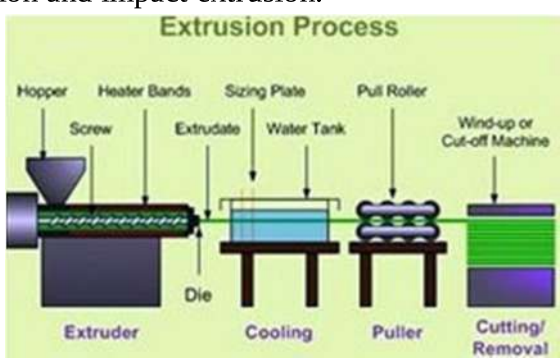


Figure: Extrusion Process

4) **Forging:** In forging process the metal is heated to a plastic state and then formed to the desired shape by pressure or impact. The various types of forging processes are flat die forging, drop forging, upset forging, press forging and roll forging.

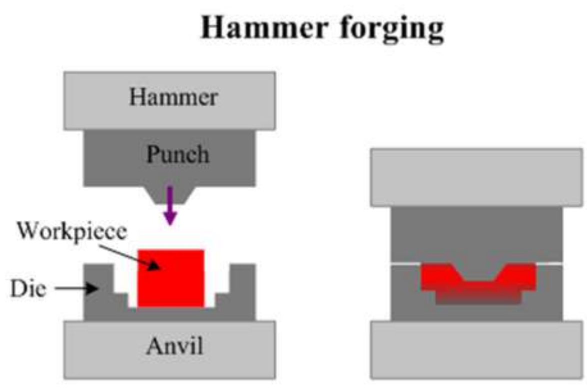


Figure: Forging Process

5) **Stamping:** In the stamping process, force is applied on the metal to cause plastic flow and to alter the size and shape of the metal part to the desired size and shape. It is a cold working process.

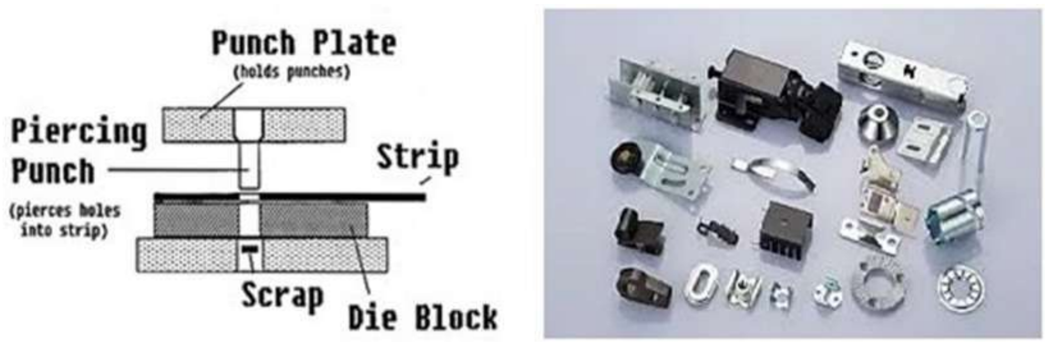


Figure: Stamping Process

6) **Spinning:** Also known as spin forming; it is a process of shaping a metal by pressing it against a form or mandrel while it is rotating on a high speed lathe.

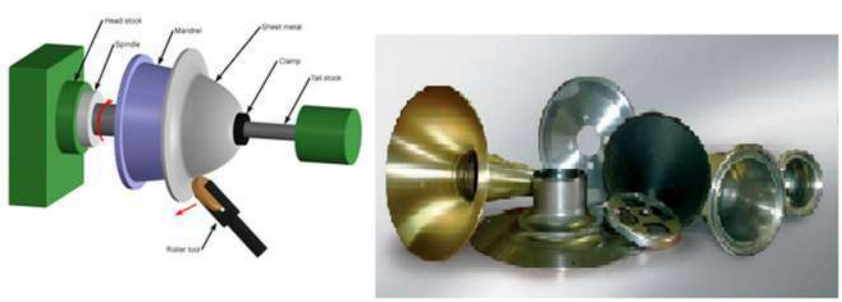


Figure: Spinning Process

<u>**Machining Processes:**</u>

1) **Turning:** In turning operation, the work piece is held in the lathe and rotated while the cutting tool or cutter removes the metal from the work piece. The various kinds of operations that can be

performed on lathe are cylindrical turning, taper turning, facing, reaming, drilling, boring thread cutting, grinding and knurling.

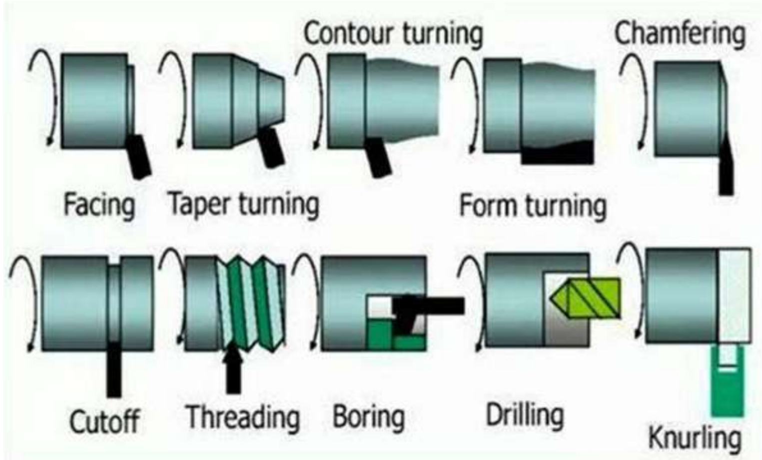
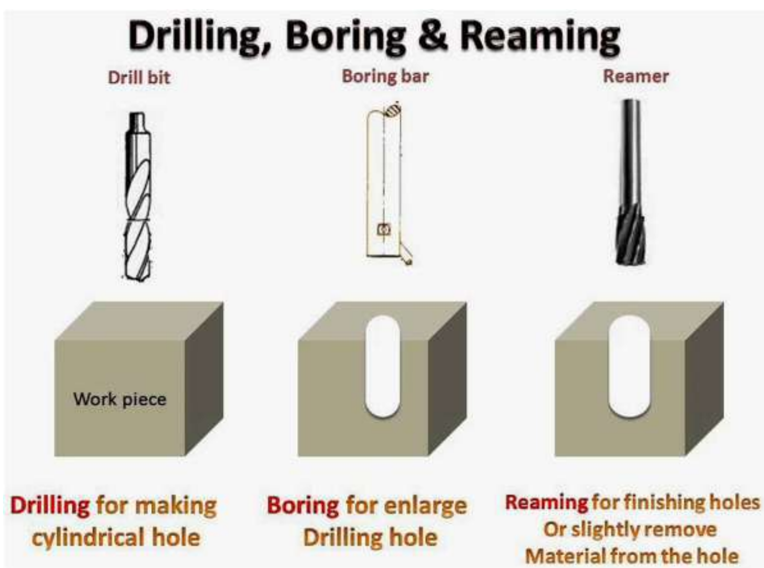


Figure: Different Types of Turning Operation

2) **Drilling and boring:** In drilling operation, a hold is produced on the work piece by forcing a rotating cutter known as drill bit through the work piece. In boring operation, an existing drilled hold is enlarged by using a cutter known as boring bit. Reaming is the finishing of a drilled hole to an accurate size using a fluted tool called a reamer.



3) **Milling:** Milling operation removes metal by feeding the work piece against a rotating multi-point cutting tool called milling cutter.

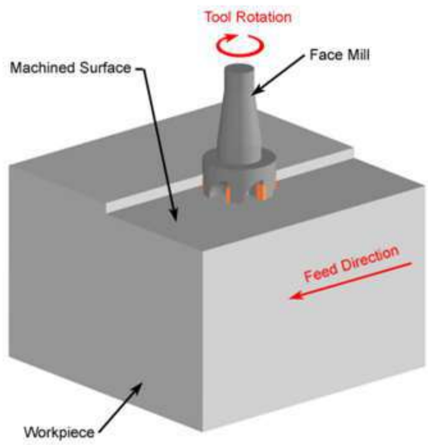


Figure: Milling Process

4) **Grinding:** Grinding process refers to the abrading or wearing away by friction of a material. It is accomplished by forcing the work piece against a rotating grinding wheel made of abrasive material. Extremely hard metals or metals hardened by heat treatment processes can be machined only by the grinding process.

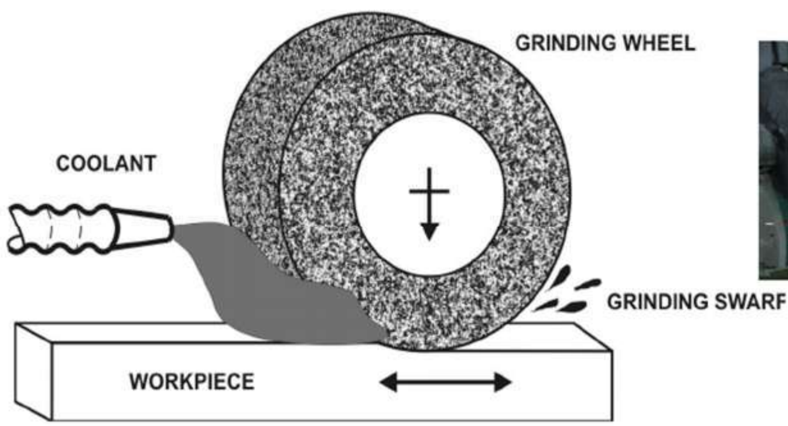


Figure: Grinding Process

5) **Shaping and planning:** In shaping or planning, plane surfaces are produced with the use of single point cutting tools. Work pieces, castings or forgings of smaller sizes are machined by shaping process, where planning process is used for machining work pieces, castings or forgings of larger sizes.

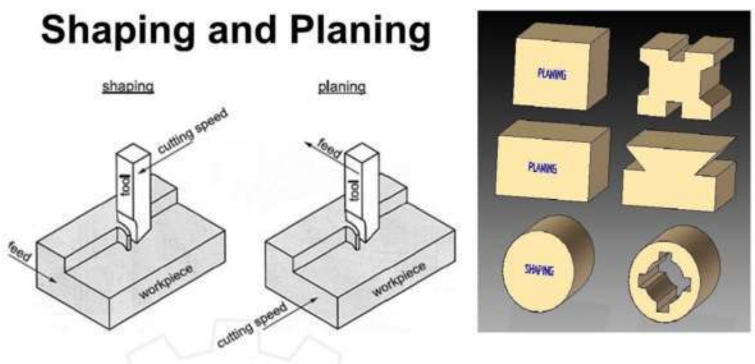


Figure: Shaping and Planing Process

Assembly Processes:

1) **Welding processes:** In welding process, two pieces of metal are joined into a single piece by fusion due to heat or combination of heat and pressure. Various types of welding processes are gas welding arc welding, resistance welding (spot welding and seam welding), plasma arc welding, electron beam welding and laser welding.

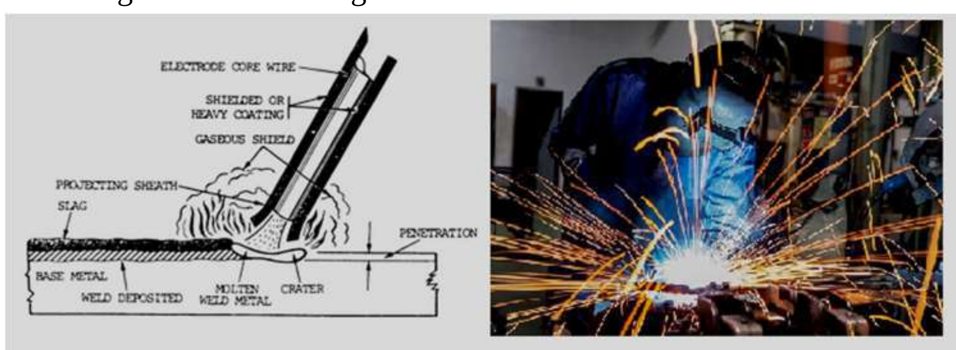
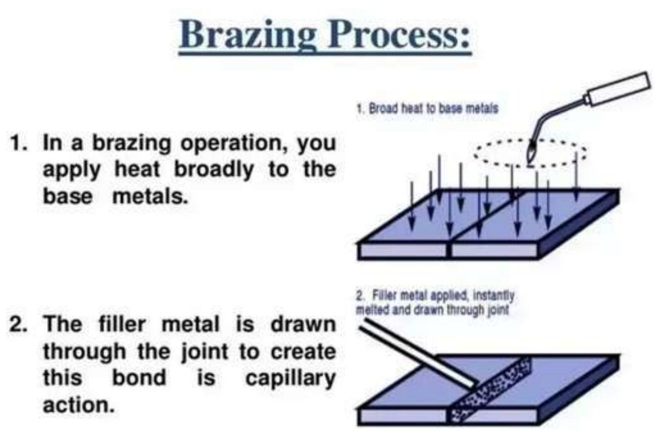


Figure: Welding Process

2) **Brazing:** Brazing is a metal joining process used for joining nonferrous alloys(either similar or dissimilar metals).The brazing alloy melts at a lower temperature than the melting point of the base metals to be joined and fills the joint between the base metals by capillary action and then solidifies on cooling.



3) **Soldering:** Soldering process is similar to brazing except that the soldering alloy is different from brazing alloy and melts at a lower temperature as compared to brazing alloy. The lead-tin base solder alloys melt and flow throughout the solder joint by the heat of the joint itself.

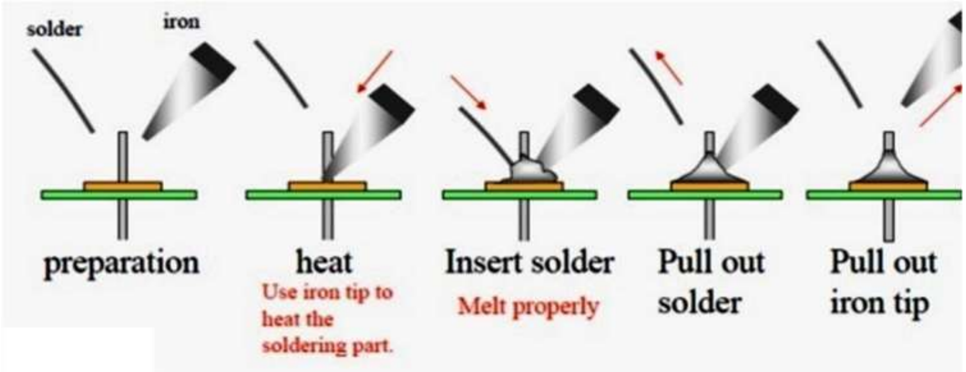


Figure: Soldering Process Step By Step

4) **Riveting:** It is the process of placing the river in a hole drilled through the overlapping surfaces of the work pieces to be joined and upsetting the head of the rivet using a riveting tool.

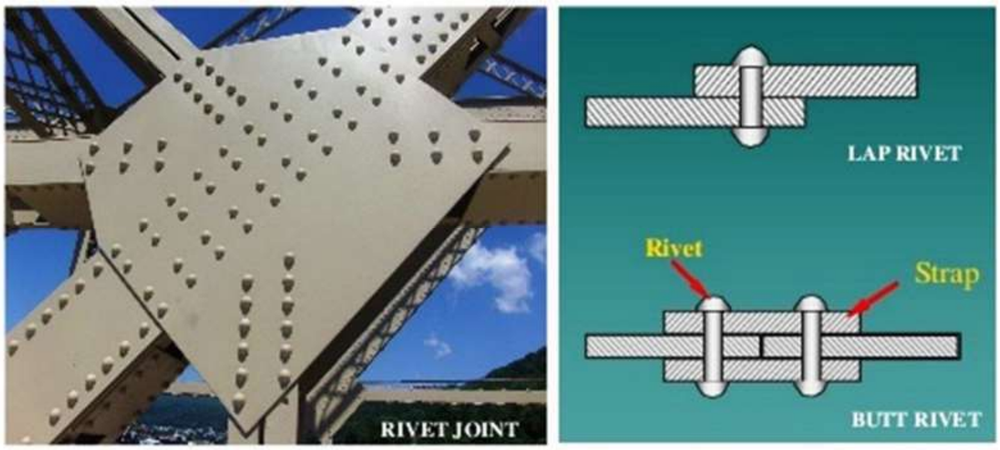


Figure: Riveting of Metals in Bridges

5) **Fastening by bolts and nuts:** When work pieces or parts of an assembly must be disassembled and reassembled, the best method of assembly is by fastening using screws, bolts and nuts.

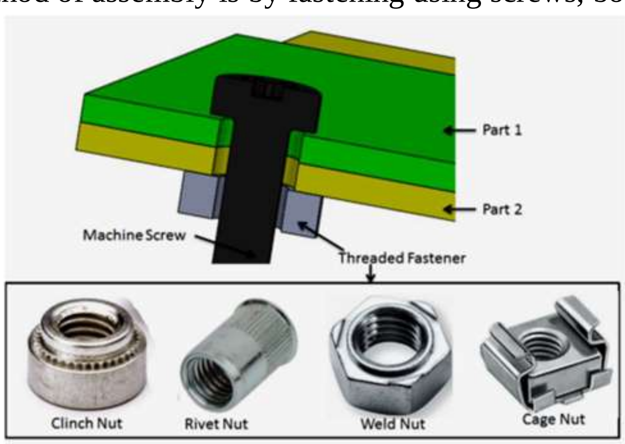


Figure: Fastening of Metals by Bolts and Nuts

6) **Assembling using adhesives:** Adhesives are used to bond almost all materials such as wood, rubber, plastics and metals.

Figure: Assembling Using Adhesives

<u>Other Types of Manufacturing:</u>

Make-To-Stock (MTS) – A factory produces goods to stock stores and showrooms. By predicting the market for their goods, the manufacturer will plan production activity in advance.

Make-To-Order (MTO) **–** The producer waits for orders before manufacturing stock. Inventory is easier to control and the owner does not need to rely as much on market demand. Customer waiting time is longer and the manufacturer needs a constant stream of orders to keep the factory in production.

Make-To-Assemble (MTA) **–** The factory produces component parts in anticipation of orders for assembly. By doing this, the manufacturer is ready to fulfill customer orders but if orders do not materialize, the producer will have a stock of unwanted parts.

<u>Process Mapping:</u>

<u>Definition of a Process:</u>

It is an activity or set of activities, which converts inputs into outputs to meet agreed customer requirements.

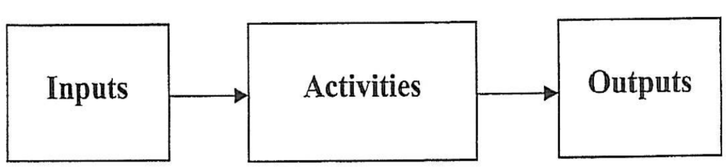


Figure: A Simple Process Chart

For example making a cup of coffee in home it contains a number of inter-related activities and these activities will need certain inputs to produce some sort of output in the form of coffee.

To deliver the final out put a cup of coffee, it need certain inputs such as coffee, milk and sugar and also need resources such as a kettle, cup, spoon, electricity/gas and water. To convert these various input into the desired output it goes through the complete process that involves a number of inter-related activities such as filling the kettle, heating the water and getting the milk from the fridge etc.

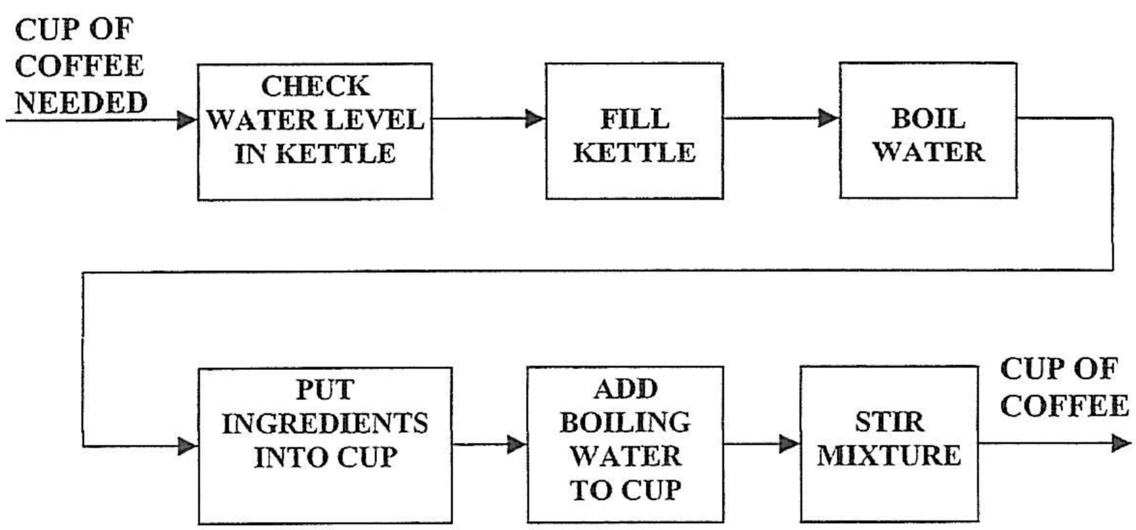
Main inputs	Key activities	Main outputs
Cup Spoon Coffee Milk Sugar Water Kettle Power (electricity/gas)	Fill kettle Heat water Get a cup Put coffee into cup Put milk into cup Put sugar into cup Fill cup with hot water	A cup of coffee

To improve processes, it is helpful to break a particular process down into its identifiable elements by constructing a map of the process which contains the straight forwards diagram and the application of logical thinking. The following methods are the most common techniques used to break down and define process. These are;

1) Process Flow charts
2) Process definition charts
3) Process Maps

Process Flow charts:

A Process Flow charts is used to show the sequence of activities within the process. A flowchart covering the activities which is shown in below (Example Process Flow Chart of making a cup of Coffee)



Example Process Flow Chart of making a cup of Coffee

Process Definition charts:

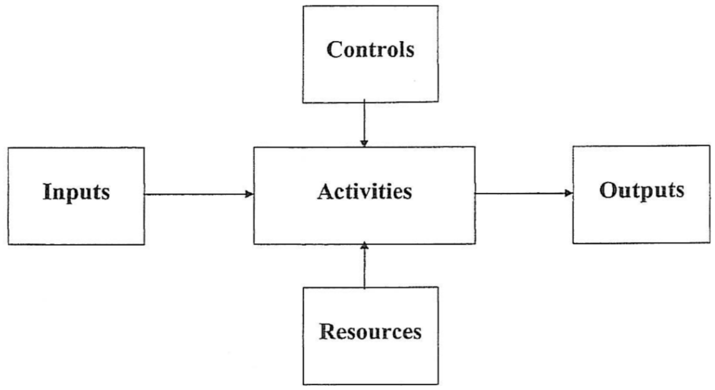


Figure: Process definition charts

This chart shows activities, inputs, outputs, control and resources.

Activities are function or tasks that make up a named process. They occur over time and have recognizable results.

Inputs are the things are transformed or used up by the process to create the output. Inputs include materials.

Outputs are the results of the activities transforming the inputs. These should normally be designed to meet customer requirements.

Controls defines, regulates and influences the process but are not transformed by it. Internal controls include procedures, budgets a timescales. External control includes legislation, standards and other professional guidelines or the availability of resources.

Resources are used to produce the outputs, but differ from inputs as they are not transformed or used up during the process. Resources will include equipments and people.

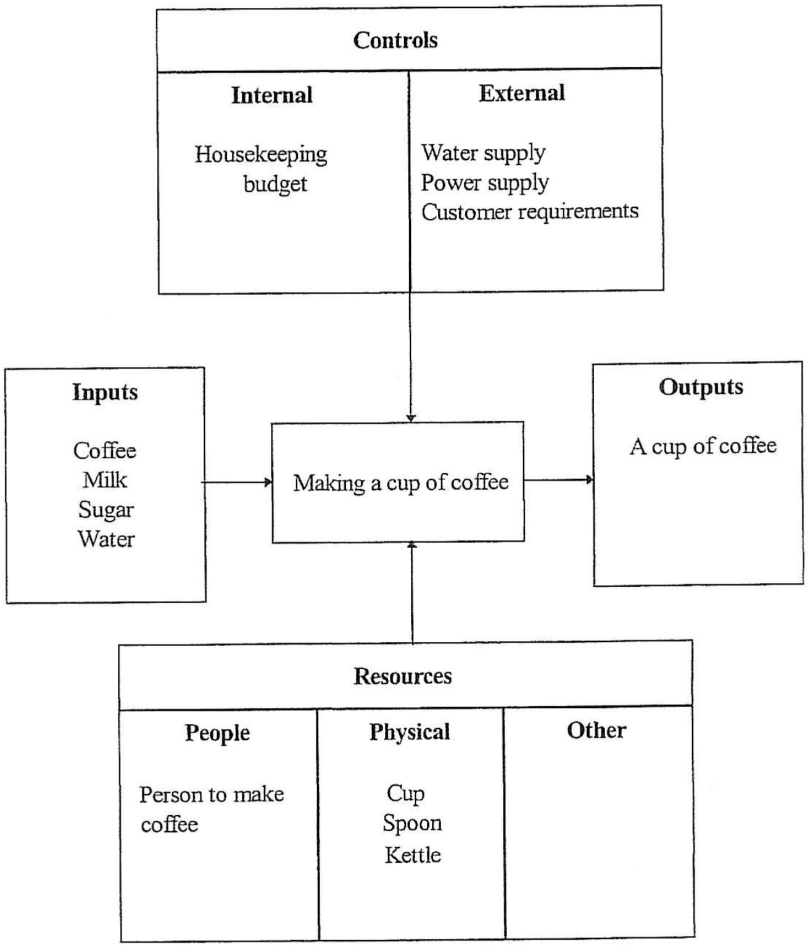
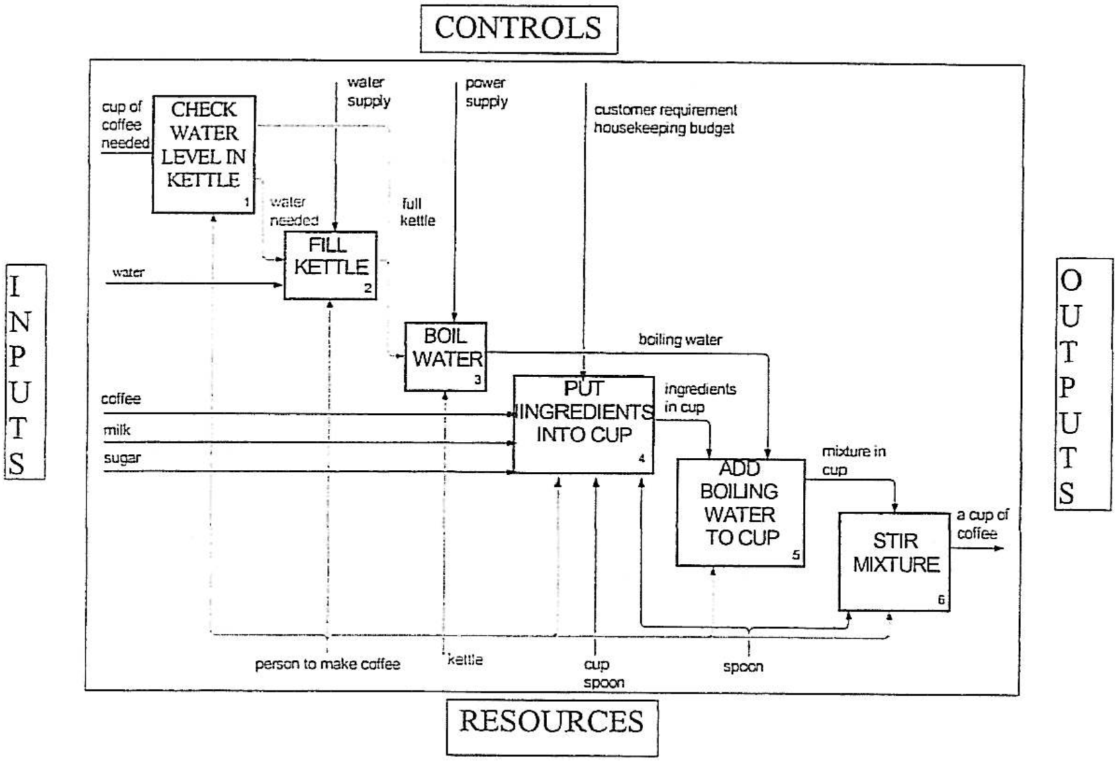


Figure: A Compote Process definition charts for making a Cup of Coffee

The Process Map:

A process map combines the process flowchart and the process definition chart and gives a picture of how people organize and perform their work. It helps them understand and clarify the sequence of activities within a process and identifies inputs, outputs, control and resources associated with the process all on one diagram.



In the above map for making a cup of coffee, shows the whole picture on one diagram, all the information gathered on the process. In the map that the outputs from activities 3 & 4 become control on activity 5and similar 5 to 6. In the first case the ingredients should be in the cup before the water is added and the water should be boiled before adding to the cup. In the latter case there would be little point in stirring the cup if the mixture had not been added.

Process Mapping In Work Environment:

Every organization delivers its final product or service to its customers through a set of inter-related process. A manufacturing company, for example will have processes to make sure;

1) Supplies of products and materials are available
2) A workforce is available
3) Product are researched and designed
4) Product are marketed and sold
5) Products are manufactured
6) Finished products are packaged and distributed
7) Income is collected suppliers are paid

How to Process Map:

For the initiation of process map that to be understood by top management regarding overviews of the key activities involved in the process. These are normally contains three different levels which is given below;

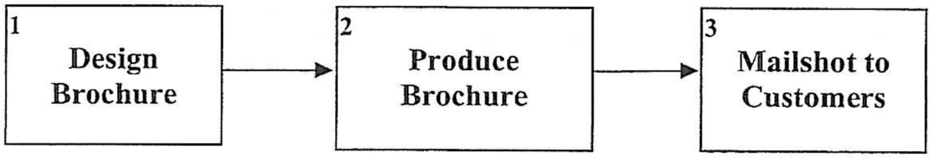


Figure: Example of Level -1 Flowchart

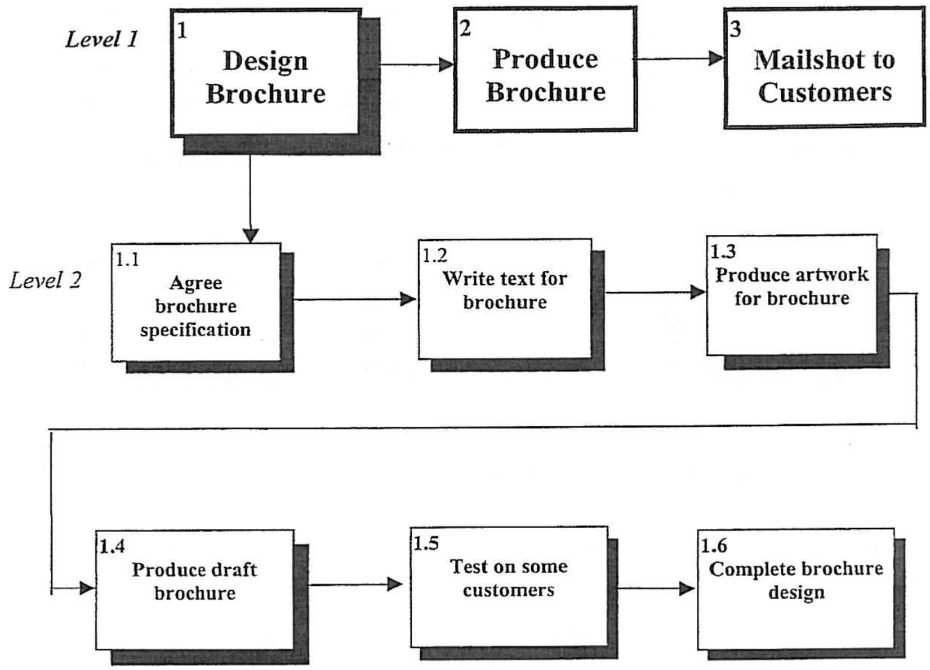


Figure: Example of Level -2 Flowchart-Design Brochure Stages of Process

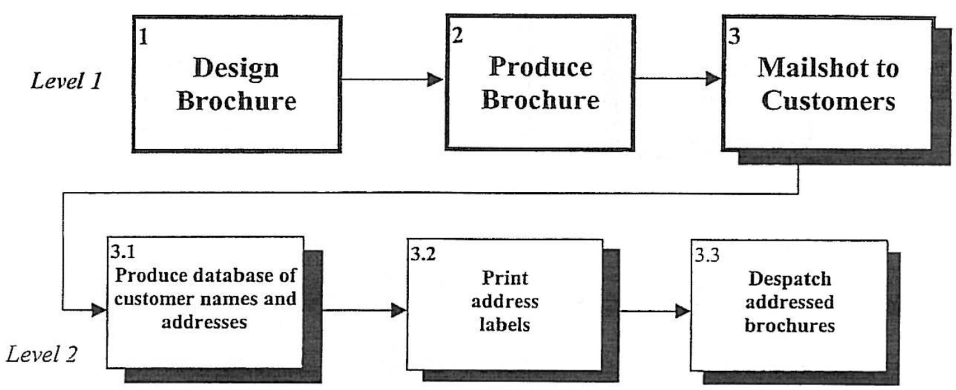


Figure: Example of Level -2 Flowchart-Design Brochure Stages of Process

To concluded, the level-1 flow chart shows a few key activities for the whole process providing a process overview. A level-2 flow chart breaks each level-1 activities into more details, it could be produce a level-3 flow chart (and level-4, level-5 etc.) in the same way. Each further level show more and detailed activities in the process.

The Process Atlas:

All organization has key processes that make up its process Atlas. While organization vary widely in size and culture they nearly all have similar top level processes, even though the individual activities in each process may differ from one organization to another. These can be split into groups as in the following example;

MANAGEMENT PROCESSES	CORE/CUSTOMER FACING PROCESSES	SUPPORT PROCESSES
• Strategic Direction; • Business Planning; and • Performance Measurement & Review	• New Product; Development; • Marketing; • Sales; • Customer Service; • Innovation; • Product/Service; Delivery; and • Manufacturing	• Procurement; • Asset Management; • People Management; • Systems Management; • Communications; • Financial Management; and • Administration

These processes cover most, if not all, of what organizations do and the detailed process Maps describe how they go about it.

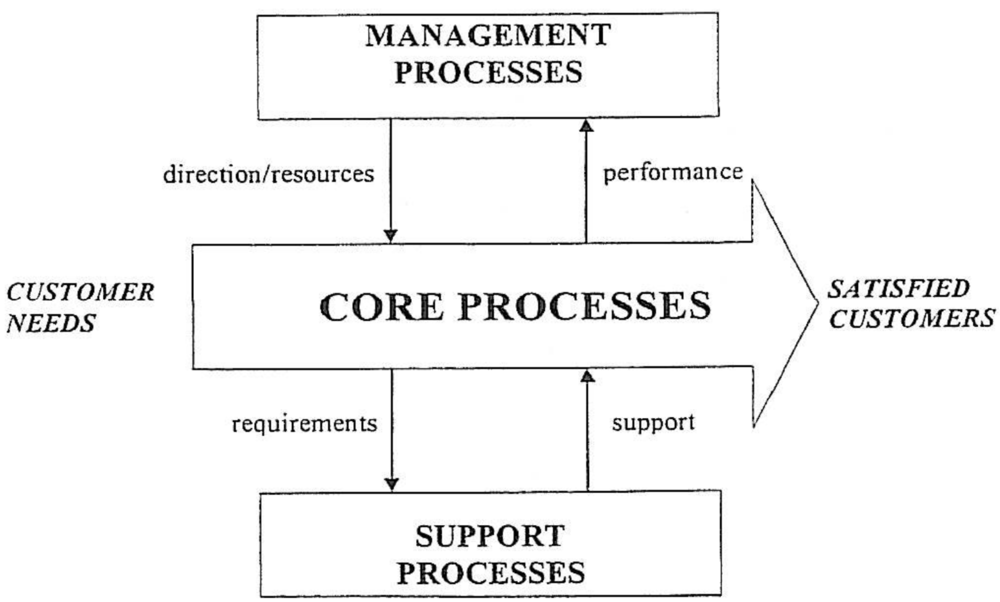


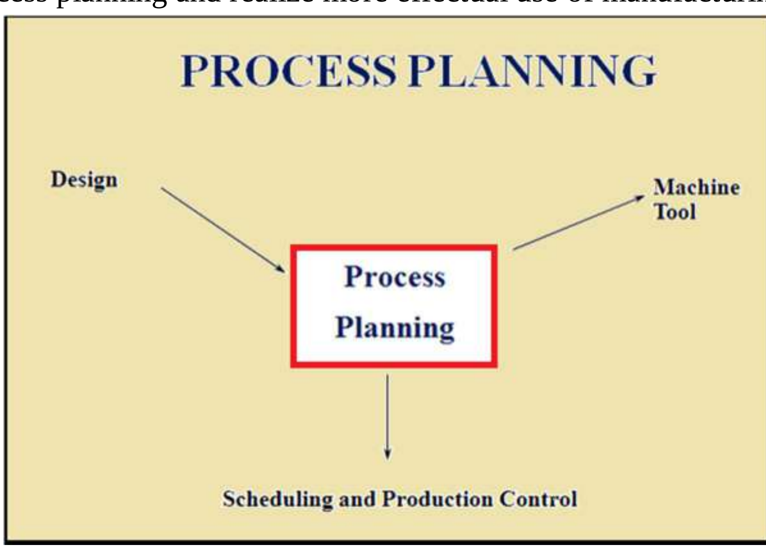
Figure: An Example of a Process Atlas

Process Mapping will help your organization: (Merits/Advantages)

1) Make sure that business process are designed to meet customer requirement
2) Review existing procedures and processes
3) Identify unnecessary steps in processes
4) Manage resources by identifying where time and resources are tied up
5) Identify the internal and external customer/ supplier chains
6) Identify weak links in the customer/ supplier chains
7) Encourage improvement in the overall process rather than individual functions
8) Become more competitive
9) Re-engineer ineffective and inefficient processes
10) See how individual roles affects and understand the whole process
11) As a first step towards benchmarking.

Manufacturing Process Planning: Definition, Scope and Elements:

In companies, planning processes can result in increased output, higher precision, and faster turnaround for vital business tasks. A process is described as a set of steps that result in a specific outcome. It converts input into output. Process planning is also called manufacturing planning, material processing, process engineering, and machine routing. It is the act of preparing detailed work instructions to produce a part. It is a complete description of specific stages in the production process. Process planning determines how the product will be produced or service will be provided. Process planning converts design information into the process steps and instructions to powerfully and effectively manufacture products. As the design process is supported by many computer-aided tools, computer-aided process planning (CAPP) has evolved to make simpler and improve process planning and realize more effectual use of manufacturing resources.



It has been documented that process planning is required for new product and services. It is the base for designing factory buildings, facility layout and selecting production equipment. It also affects the job design and quality control.

Objective of Manufacturing Process Planning:

- The chief of process planning is to augment and modernize the business methods of a company. Process planning is planned to renovate design specification into manufacturing instructions and to make products within the function and quality specification at the least possible costs.
- This will result in reduced costs, due to fewer staff required to complete the same process, higher competence, by eradicating process steps such as loops and bottlenecks, greater precision, by including checkpoints and success measures to make sure process steps are completed precisely, better understanding by all employees to fulfill their department objectives.
- Process planning deals with the selection of the processes and the determination of conditions of the processes. The particular operations and conditions have to be realized in order to change raw material into a specified shape. All the specifications and conditions of operations are included in the process plan.
- The process plan is a certificate such as engineering drawing. Both the engineering drawing and the process plan present the fundamental document for the manufacturing of products.
- Process planning influences time to market and productions cost. Consequently the planning activities have immense importance for competitive advantage.

Effect of Manufacturing Process Planning:

Manufacturing Process Planning provides customers a single, scalable and secure source of manufacturing data that supports lifecycle processes from engineering through production. With a fully managed, single source of knowledge for products, processes, resources and plants, customers can increase manufacturing's influence on product innovation to drastically improve profitability, time-to-market and quality. Leading manufacturers are looking for technologies and methodologies that allow them to efficiently author, simulate and manage manufacturing information throughout their organization and with external suppliers. Manufacturers want software tools that can align manufacturing plans quickly and intelligently based on changing product configurations. Manufacturing process planner (MPP) allows design and manufacturing engineers to concurrently develop product and manufacturing process definitions. This ensures that manufacturing constraints are reconciled during product design and vice versa. Using Teamcenter powerful change management capabilities, manufacturers can quickly react to changes originating at any point of the design/build lifecycle.

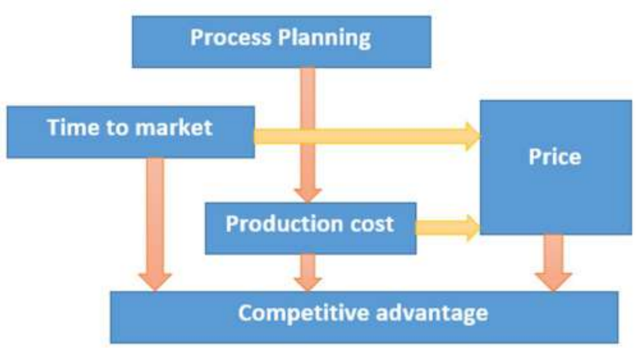


Figure: Effects of Manufacturing Process Planning

Advantages of Manufacturing Process Planning are;

- Ensure overall product and process quality
- Quicken new product introductions
- Abbreviate time-to-production
- Quickly react to change at any stage of the design and help to build process
- Reduction in operating costs
- Allow engineers, designers and shop floor personnel to collaborate efficiently

Principles of Manufacturing Process Planning:

General principles for evaluating or enhancing processes are as follows:

1. First define the outputs, and then look toward the inputs needed to achieve those outputs.
2. Describe the goals of the process, and assess them frequently to make sure they are still appropriate. This would include specific measures like quality scores and turnaround times.
3. When mapped, the process should appear as a logical flow, without loops back to earlier steps or departments.
4. Any step executed needs to be included in the documentation. If not, it should be eliminated or documented, depending on whether or not it's necessary to the process.
5. People involved in the process should be consulted, as they often have the most current information.

Process planning includes the activities and functions to develop a comprehensive plans and instructions to produce a part. The planning starts with engineering drawings, specifications, parts or material lists and a forecast of demand. The results of the planning are routings which specify operations, operation sequences, work centres, standards, tooling and fixtures. This routing becomes a major input to the manufacturing resource planning system to define operations for production activity control purposes and define required resources for capacity requirements planning purposes.

Process plans which characteristically offer more detailed, step-by-step work instructions including dimensions linked to individual operations, machining parameters, set-up instructions, and quality assurance checkpoints. Process plans results in fabrication and assembly drawings to support manufacture and annual process planning is based on a manufacturing engineer's experience and knowledge of production facilities, equipment, their capabilities, processes, and tooling. But process planning is very lengthy and the results differ based on the person doing the planning.

Major Steps in Manufacturing Process planning:

Manufacturing process planning has numerous steps to complete the project that include the definition, documentation, review and improvement of steps in business processes used in a company.

Definition: The first step is to describe what the process should accomplish. It includes queries like, what is the output of this process? Who receives the output, and how do they define success?, What are the inputs for the process?, Are there defined success measures in place - such as turnaround time or quality scores? And Are there specific checkpoints in the process that need to be addressed?

Documentation: During the documentation stage, interviews are conducted with company personnel to determine the steps and actions they take as part of a specific business process. The results of these interviews is written down, generally in the form of a flow chart, with copies of any forms used or attached. These flow charts are given to the involved departments to review, to make sure information has been correctly captured in the chart.

Review: Next, the flow charts are reviewed for potential problem areas.

Process planning in manufacturing may include the following activities:

1. Selection of raw-stock,
2. Determination of machining methods,
3. Selection of machine tools,
4. Selection of cutting tools,
5. Selection or design of fixtures and jigs,
6. Determination of set-up,
7. Determination of machining sequences,
8. Calculations or determination of cutting conditions,
9. Calculation and planning of tool paths,
10. Processing the process plan

Computer Aided Process Planning:

Manufacturers have been following an evolutionary step to improve and computerize process planning in the following five stages:

Stage I - Manual classification; standardized process plans

Stage II - Computer maintained process plans

Stage III - Variant CAPP

Stage IV - Generative CAPP

Stage V - Dynamic, generative CAPP

Earlier to CAPP, producers attempted to triumph over the issues of manual process planning by basic categorization of parts into families and developing standardized process plans for parts families that is called

Stage I. When a new part is initiated, the process plan for that family would be manually recovered, marked-up and retyped. While this improved output but it did not enhance the quality of the planning of processes.

Computer-aided process planning originally developed as a device to electronically store a process plan once it was shaped, recover it, amend it for a new part and print the plan. It is called **Stage II.** Other ability of this stage is table-driven cost and standard estimating systems.

Stage III: Computer-aided approach of variant CAPP is based on a Group Technology coding and classification approach to recognize huge number of part attributes or parameters. These attributes permit the system to choose a baseline process plan for the part family and achieve about ninety percent of the planning work. The schemer will add the remaining ten percent of the effort modifying or fine-tuning the process plan. The baseline process plans stored in the computer are manually entered using a super planner concept that is, developing standardized plans based on the accumulated experience and knowledge of multiple planners and manufacturing engineers.

Stage IV: It is generative CAPP. In this stage, process planning decision rules are developed into the system. These decision rules will work based on a part's group technology or features technology coding to produce a process plan that will require minimal manual interaction and modification.

While CAPP systems move towards being generative, a pure generative system that can create a complete process plan from part classification and other design data is a goal of the future. These types of generative system will utilize artificial intelligence type capabilities to produce process plans as well as be fully integrated in a CIM environment. An additional step in this stage is dynamic, generative CAPP which would consider plant and machine capacities, tooling availability, work center and equipment loads, and equipment status in developing process plans.

The process plan developed with a CAPP system at Stage V would differ in due course depending on the resources and workload in the factory. Dynamic, generative CAPP also entails the need for online display of the process plan on a work order oriented basis to cover that the appropriate process plan was provided to the floor.

There are numerous advantages of this type of process planning. It can decrease the skill required of a planner. It can reduce the process planning time. It can reduce both process planning and manufacturing cost. It can create more consistent plans. It can produce more accurate plans. It can increase productivity. Automated process planning is done for shortening the lead-time, manufacturability feedback, lowering the production cost and consistent process plans. Advantages of Computer-aided Process Planning include reduced demand on the skilled planner, reduced process planning time, reduced process planning and manufacturing cost, created more consistent plans, produced accurate plans, increased productivity, increased high flexibility, attained high efficiency, attained adequate high product quality and possibility of integration with the other automated functions and systems.

Manufacturing Process Planning delivers essential process planning potential for all manufacturing industries. Using Manufacturing Process Planning, process planners can powerfully create and authenticate the original process plan using the product structure from product engineering, modify the plan to specific requirements, and link products and resources to the steps of the plan.

To summarize, Process Planning is important action in a production enterprise that verifies which processes, materials, and instructions will be used to produce a product. Process planning describes a manufacturing facility, processes and parameters which are to be used to change materials from a primary form to a predetermined final stage.

Manufacturing Concept Planning:

The solution of manufacturing process planning is a complicated and combined problem therefore it is necessary to divide the tasks into hierarchical levels. The first level of this hierarchy is called **preliminary process planning or Manufacturing concept planning**, which is the conceptual level of the planning process.

The most important tasks of preliminary process planning are;

(1) The preparation of process planning of blank manufacturing, the part manufacturing and the assembly;

(2) Correction of the design documents in the view point of manufacturability and assemblebility;

(3) Selection of manufacturing system;

(4) Analysis of the manufacturing tasks and estimation of manufacturing cost and time data.

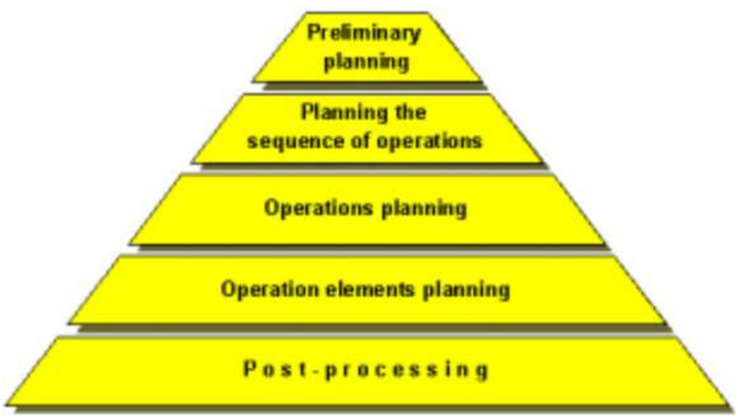


Figure. Levels of manufacturing process planning

Function of Preliminary Process Planning:

The preliminary process planning is different from other levels in many aspects. The most important difference is that some tasks regard the assembled product as a basic unit instead of part. In other words the preliminary planning examines in the same time every part of the product and their influences whereas the object of other levels is only one part.

The tasks of the preliminary process planning are as follows:

1) Collecting the technological data for the process planning of the blank manufacturing, the part manufacturing and the assembly; rationalizing of manufacturing process; preparing of manufacturability and assemblebility correct part, assembly and blank design documentation.
2) Determining the strategy of process planning which means the selection of manufacturing systems and actual manufacturing variant.
3) Analyzing the manufacturing tasks, estimation of manufacturing cost and time data.

In the case of new order the process of preliminary planning is more complicated. The necessary steps are the following:

1) Preparation of manufacturability and assemblebility correct design documentation.
2) Selection of blank types and design of blank parts.
3) Analysis of manufacturing tasks.
4) Assigning the manufacturing system.
5) Selection of the optimal manufacturing variant.
6) Estimation of manufacturing cost and time data.

The connection between the preliminary planning and other areas is determined by these planning tasks. Briefly the data flow between the preliminary planning and the management, the design engineering unit and the production planning unit is bi-directional, but the connection to fields of process planning is just data supply (Figure.).

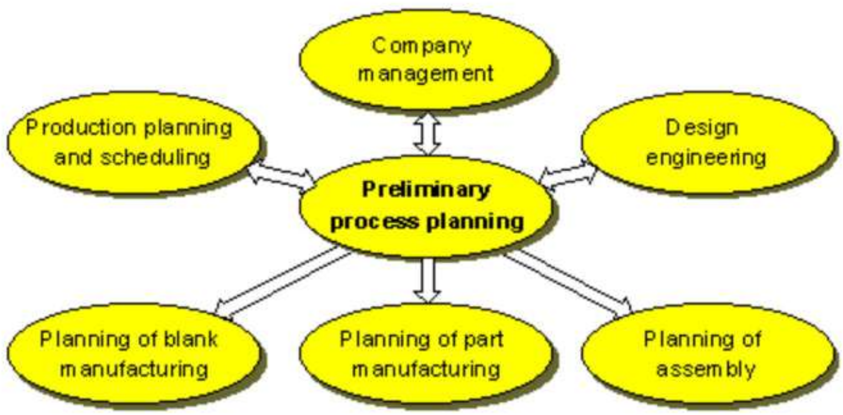


Figure: The connection between the preliminary planning and other areas

The Process of Preliminary Planning:

The aim of manufacturing process planning is to generate the manufacturing documentation for fulfilling of planned production projects by production unit considering the financial aims of the company management. Therefore one of the basic item of information of preliminary planning is the long terminate production plan. The actual design documentation, which consists of assembly drawings, detailed drawings, BOM lists and other descriptions, is provided by the design engineering unit.

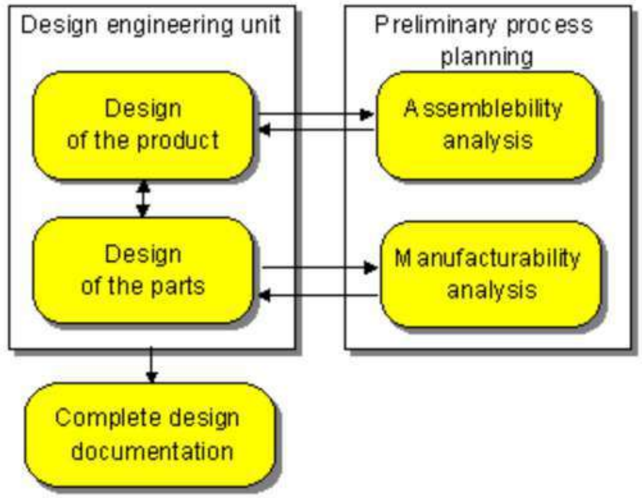


Figure: The first step of preliminary planning is the design analysis

The aim of design analysis is rationalizing of manufacturing process, lowering costs by analyzing the product from the viewpoint of manufacturing. The design analysis indicates a feedback to the design engineering unit and it assures the correct and complete design documentation. The design analysis consists of two main tasks: the analysis of assemblebility and the analysis of manufacturability.

The purpose of analysis of assemblebility is to study the existence of topological conditions of assembly. This is a complicated problem, which is hard to automate and it needs the detailed understanding of the functional connection of the product. The assemblebility analysis contains the measurement chain analysis, which is an exact mathematical problem.

The second step is the manufacturability analysis of the parts, which may indicate design modification demands, too. The necessary data of this analysis is the manufacturing capacity (list of manufacturing methods, accuracy, size of workspace, etc.) of manufacturing environment (machine tools, tools, jigs and fixtures, etc.). The analysis can be made on two approaches, which are

a) **Rule-based approach of manufacturability analysis;**
b) **Plan-based approach of manufacturability analysis**

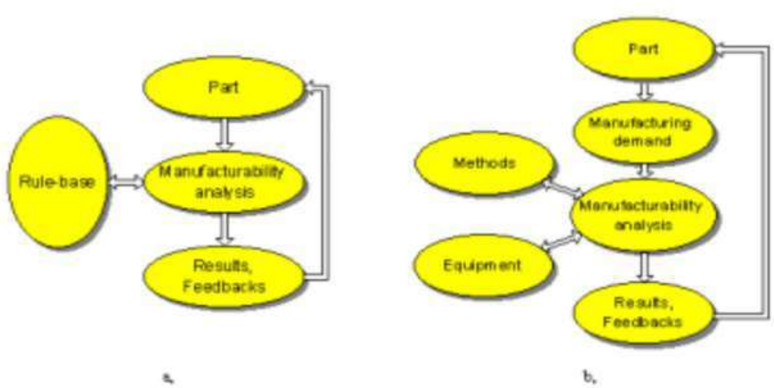


Figure: Manufacturability analysis of the parts (Rule Based and Planned Based Approach)

In the case of rule-based approach, the analysis is executed directly on geometrical data by rules. The rules are domain and environment specific, because the general solution of the problem is impossible or it needs so large a set of rules, which can be unmanageable and utilizable.

In case of plan-based approach, the base of the analysis is a skeletal process plan. On the strength of geometrical data of the part the manufacturing demands are detected, and manufacturing sub-processes can be assigned. The analysis is suitable if the required manufacturing demands can be satisfied on the potential manufacturing system.

Requirements of Good Manufacturing and Assembly Lines/Layout:

Requirements of Good Manufacturing Practices:

Good manufacturing practices (GMP) are the practices required in order to conform to the guidelines recommended by agencies that control the authorization and licensing of the manufacture and sale of food and beverages, cosmetics, pharmaceutical products, dietary supplements,[4] and medical devices. These guidelines provide minimum requirements that a manufacturer must meet to assure that their products are consistently high in quality, from batch to batch, for their intended use. The rules that govern each industry may differ significantly; however, the main purpose of GMP is always to prevent harm from occurring to the end user. It include ensuring the end product is free from contamination, that it is consistent in its manufacture, that its manufacture has been well documented, that personnel are well trained, and that the product has been checked for quality more than just at the end phase. GMP is typically ensured through the effective use of a quality management system (QMS).

Good manufacturing practice guidelines provide guidance for manufacturing, testing, and quality assurance in order to ensure that a manufactured product is safe for human consumption or use. All guideline follows a few basic principles:

1) Manufacturing facilities must maintain a clean and hygienic manufacturing area.
2) Manufacturing facilities must maintain controlled environmental conditions in order to prevent cross-contamination for human consumption or use.
3) Manufacturing processes must be clearly defined and controlled.
4) Instructions and procedures must be written in clear and unambiguous language using good documentation practices.
5) Operators must be trained to carry out and document procedures.
6) Records must be made, manually or electronically, during manufacture that demonstrate that all the steps required by the defined procedures and instructions were in fact taken and that the quantity and quality of the food or drug was as expected.
7) Records of manufacture (including distribution) that enable the complete history of a batch to be traced must be retained in a comprehensible and accessible form.
8) Any distribution of products must minimize any risk to their quality.

9) A system must be in place for recalling any batch from sale or supply.
10) Complaints about marketed products must be examined, the causes of quality defects must be investigated, and appropriate measures must be taken with respect to the defective products and to prevent recurrence.

Requirements of Good Assembly Lines:

Assembly Lines:

1) An arrangement of machines, equipment, and workers in which work passes from operation to operation in direct line until the product is assembled.
2) A process for turning out a finished product in a mechanically efficient manner.
3) A manufacturing tool, first made popular by Henry Ford in his manufacturing of automobiles. The principle of an assembly line is that each worker is assigned one very specific task, which he or she simply repeats, and then the process moves to the next worker who does his or her task, until the task is completed and the product is made. It is a way to mass produce goods quickly and efficiently. All workers do not have to be human; robotic workers can make up an assembly line as well.

The assembly line was important during this time due to its purpose in mass production. But, to this day is still used as the main form of manufacturing and is a big factor in commerce around the globe. It allowed product to be produced less expensively for both the consumer and the company. It saved the companies money by helping them pay less for their labor per part produced.

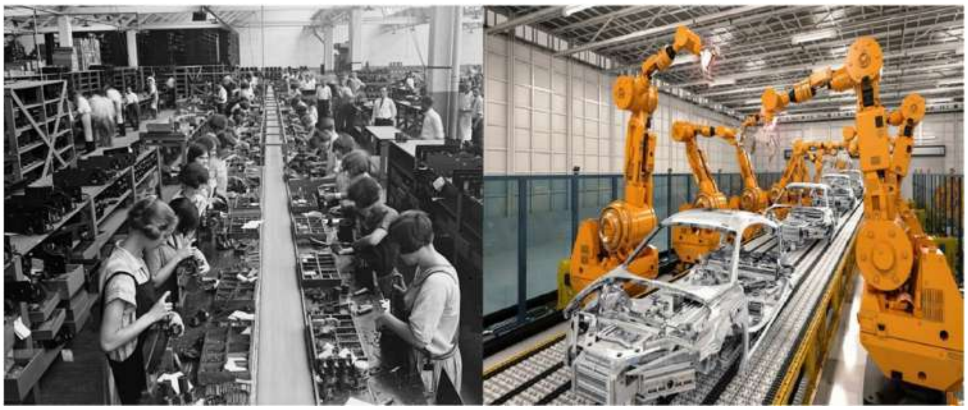


Figure: Past and Present of Assembly Line

Making products by hand might be adequate in the early stages of launching a company, but as demand grows, small business owners often need to find ways to produce more goods at a faster pace. Assembly-line production is a common manufacturing method that carries several significant benefits and drawbacks.

Specialization of Labor and Capital

An assembly line is a sequence of workers and machines that each perform a set of specific tasks on a product that move it closer to a finished form. The primary benefit of assembly lines is that they allow workers and machines to specialize at performing specific tasks, which can increase productivity. Large-scale assembly lines can allow for mass production of goods that would not be possible if products were made from start to finish by a single worker. The high productivity of mass production can also result in lower cost per unit produced than other manufacturing methods.

Uniform Product

Another benefit of using an assembly line in the manufacturing process is that a regimented production process helps ensure a uniform product. In other words, the products made by an assembly line are not likely to exhibit much variation. If one worker created an entire good scratch, his product might be significantly different from the goods produced by another employee.

Initial Cost

While assembly lines can potentially reduce the total cost of product per unit, they can have a high initial cost. Assembly lines require a significant amount of space to operate, and renting factory floor space can be expensive. In addition, assembly lines often make use of large, specialized machines that can be expensive to purchase and difficult for small businesses to finance. An assembly line needs to increase productivity and sales enough to cover the initial costs to be considered a sound investment.

Flexibility

Assembly lines are geared toward producing a specific type of product in mass quantities, which can make a company less flexible if it wants to shift production to different types of products. For example, the machinery used on an assembly line used to make automobiles might have little application for other tasks. Shifting operations to produce different products in an assembly line environment can be costly and might require additional training and the purchase of new machinery.

Plant/Facility Layout:

1) Plant layout refers to the physical arrangement of manufacturing facilities, which are used in production.
2) Plant layout is a plan of an optimum arrangement of facilities including personnel, operating equipment, storage space, material handling equipment and all other supporting services along with the design of best structure to contain all these facilities.

Objectives of Plant Layout:

The primary goal of the plant layout is to maximise the profit by arrangement of all the plant facilities to the best advantage of total manufacturing of the product.

1) Streamline the flow of materials through the plant.
2) Facilitate the manufacturing process.
3) Maintain high turnover of in-process inventory.

4) Minimise materials handling and cost.
5) Effective utilization of men, equipment and space.
6) Make effective utilization of cubic space.
7) Flexibility of manufacturing operations and arrangements.
8) Provide for employee convenience, safety and comfort.
9) Minimize investment in equipment.
10) Minimize overall production time.
11) Maintain flexibility of arrangement and operation.
12) Facilitate the organizational structure

Factor Affecting Facility Layout:

1) Plant location and building
2) Nature of product
3) Types of industry
4) Plant environment
5) Spatial requirement
6) Repair and Maintenance
7) Balance
8) Management policy
9) Human needs
10) Types of machinery and equipments

Principles of Plant Layout:

1. Principle of integration: A good layout is one that integrates men, materials, machines and supporting services and others in order to get the optimum utilization of resources and maximum effectiveness.

2. Principle of minimum distance: This principle is concerned with the minimum travel (or movement) of man and materials.

3. Principle of cubic space utilization: The good layout is one that utilizes both horizontal and vertical space. Also the height is also to be utilized effectively.

4. Principle of flow: A good layout is one that makes the materials to move in forward direction towards the completion stage.

5. Principle of maximum flexibility: The good layout is one that can be altered without much cost and time, *i.e.*, future requirements should be taken into account while designing the present layout.

6. Principle of safety, security and satisfaction: A good layout is one that gives due consideration to workers safety and satisfaction and safeguards the plant and machinery against fire, theft, etc.

7. Principle of minimum handling: A good layout is one that reduces the material handling to the minimum.

Types of Layout:

1) **Process layout (or Functional Layout or Job shop layout)**
2) **Product layout (or Line Processing Layout or Flow Line Layout)**
3) **Static layout (or Fixed position layout)**
4) **Group technology layout (or Cellular Manufacturing Layout)**
5) **Combination layout (or Hybrid Layout)**

Process Layout:

- **i.** Process layout is recommended for batch production.
- **ii.** All machines performing similar type of operations are grouped at one location in the process layout *e.g.*, all lathes, milling machines, etc. are grouped in the shop will be clustered in like groups.
- **iii.** Thus, in process layout the arrangement of facilities are grouped together according to their functions.
- **iv.** Process layout are quite common in service environment. Example including hospital, universities, banks, auto repair shops, airlines and public libraries.
- **v.** Universities have separate schools or departments that concentrated on one area of study such as business management, engineering, science or math.
- **vi.** A hospital provides a good example of a process layout in the service sector, customer (patients) go to radiology for X-rays and to the Lab for blood tests.

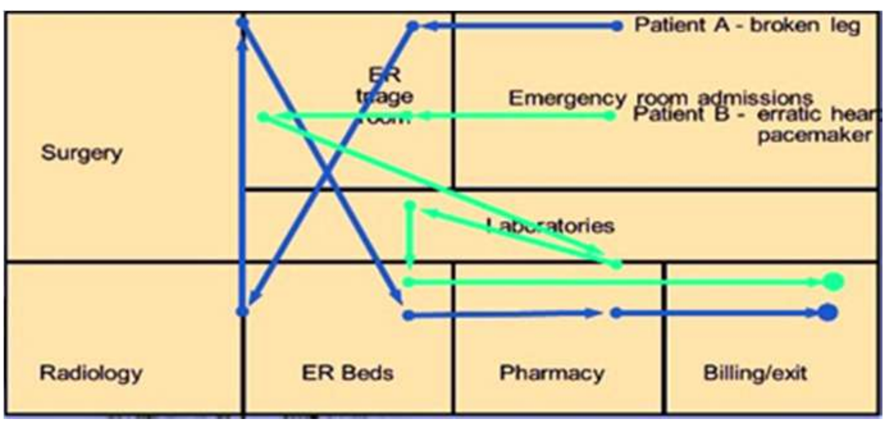


Figure: Process Oriented Layout for a Hospital

Advantages:

1) Reduced investment of machines as they are general purpose machines
2) Greater flexibility in the production
3) Greater scope for expansion as the capabilities of different lines can be easily increased
4) Easy to handle breakdown of equipment by transferring work to another machine or station
5) Full utilization of equipments

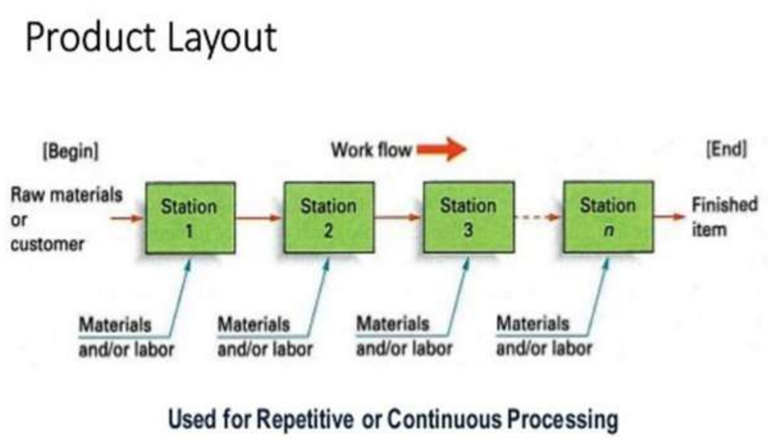
6) There is greater incentive to individual worker to increase his performance.

Disadvantages:

1) Difficulty in production control
2) Difficulty in the movement of materials due to mechanical equipments and devices.
3) Production time is more as work in progress has to travel from place to place in search of machine.
4) Lower productivity due to number of set-ups.
5) Throughput (time gap between in and out in the process) time is longer.

Product Layout:

i. In this type of layout, machines and auxiliary services are located according to the processing sequence of the product.
ii. If the volume of production of one or more products is large, the facilities can be arranged to achieve efficient flow of materials and lower cost per unit.
iii. Special purpose machines are used which perform the required function quickly and reliably.



Advantages:

1) Economy of manufacturing time
2) Better production control
3) Required less floor area per unit of production
4) Flow of product will be smooth
5) Less in process inventory
6) Throughput time is less
7) Simplified production, planning and control system
8) Perfect line balancing
9) Manufacturing cycle is short due to uninterrupted flow of materials.
10) Unskilled worker can learn and manage the production.

Disadvantages:

1) Product layout is known for its inflexibility
2) Layout is quite expensive
3) Difficult for supervision
4) Difficult in future expansion
5) Change in product design may require major alteration in the layout
6) Any breakdown of equipments along a production line can disrupt the whole system.

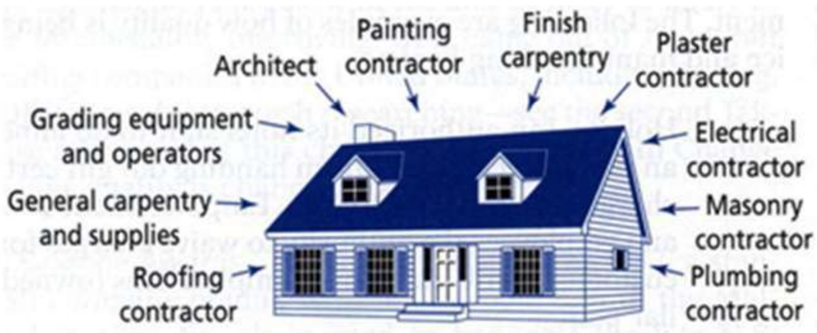
Process Layout vs. Product Layout:

	Process layout	**Product layout**
1. Investment	Comparatively low investment needed	Needs high investment in machine/equipment
2. Duration of Production	Production time cannot be economized due to frequent movement of men and material.	Needs less manufacturing times as the economy in time can be planned in the beginning
3. Immobilization due to Breakdown	Breakdown of any machine does not immobilize the whole system	Break down of any unit/component immobilizes the whole system
4. Adjustability to changes	Flexible as different section can adjust ht operation according to operation	Inflexible as each machine can perform pre-designed operation only
5. Floor space	Require more space.	Requires less space.
6. Men/Equipment Utilization	Comparatively better utilization	Not to full capacity
7. material handling	Involves greater handling of material requiring more time, money and efforts.	Lesser amount of material handling and comparatively lesser time, money and efforts
8. Demand and supply relationship	Co-ordination between demand and supply is likely to be difficulty as these made to order.	Proper co-ordination between demand and as these are made to stock
9. Control and Inspection	Comparatively lesser efforts on control are needed.	Specialized and expertise control is required thus increasing supervision costs

Fixed Position Layout:

This is also called the project type of layout. In this type of layout, the material, or major components remain in a fixed location and tools, machinery, men and other materials are brought to this location.
This type of layout is suitable when one or a few pieces of identical heavy products are to be manufactured and when the assembly consists of large number of heavy parts, the cost of transportation of these parts is very high.

Fixed position layout



Advantages:

1) Men & machine can be used for a while variety of operation producing different products.
2) Helps in jobs enlargement and upgrades the skill of the operators
3) Greater flexibility with this type of layout
4) Layout capital investment is lower
5) The worker identifies themselves with a product in which they take interest and pride in doing the job.

Disadvantages:

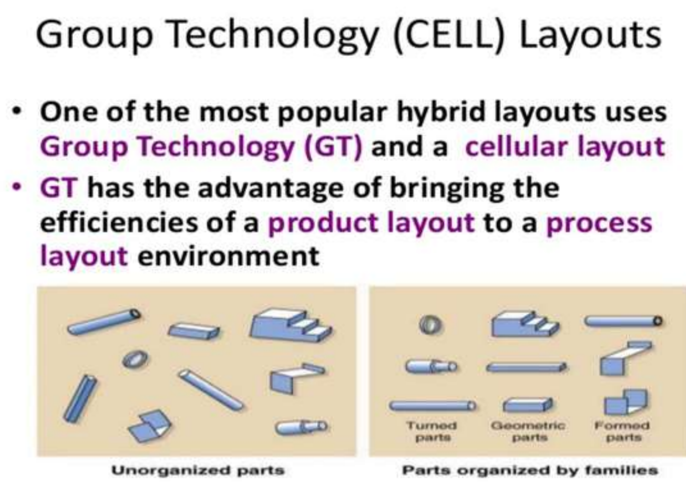
1) High cost of tool and machinery
2) Difficult to transporting a bulky product
3) Difficult in material handling specially for heavy products
4) Cost of transportation is very high
5) It needs highly skilled and multi-tasking workers

Cellular Manufacturing Systems (Group Technology):

i. In Group Technology or Cellular manufacturing layout, machines are grouped into cell and the cell function somewhat like a product layout within a larger shop or process layout.
ii. A grouping of equipment for performing a sequence of operations on family of similar components or products has become all the important.
iii. Group technology (GT) is the analysis and comparisons of items to group them into families with similar characteristics.
iv. GT can be used to develop a hybrid between pure process layout and pure flow line (product) layout.
v. This technique is very useful for companies that produce variety of parts in small batches to enable them to take advantage and economics of flow line layout.

vi. The application of group technology involve two basic steps, first is to determine components families or group and in second step in applying group technology is to arrange the plant equipment used to process a particular family of components.

vii. In group technology layout, the objective is to minimize the sum of the cost of transportation and the cost of equipments. So this is called a multi- objective layout.



Advantages:

1) Lower work in process inventories
2) Reduce materials handling costs
3) Shorter flow times in production
4) Simplified production planning (materials & labour)
5) Increase operator responsibilities
6) Improved visual control and facilitating quicker setups
7) Improved overall performance by lower production costs
8) Quality also tends to improve
9) Components standardization and rationalization
10) Reduce paper work and overall production time.

Disadvantages:

1) Reduce manufacturing flexibility
2) Potentially increased machine down time
3) For duplicate piece of equipment may be needed so that parts need not be transported between cell
4) Product mix is completely dissimilar
5) This type of layout may not feasible for all situation

Cellular Manufacturing Formation:

Cellular manufacturing uses the principle of group technology by grouping parts with similar characteristics into part-families and corresponding machines into machine cells in order to achieve higher production efficiency compared to traditional manufacturing. Cellular manufacturing is an integral part of lean manufacturing**.**

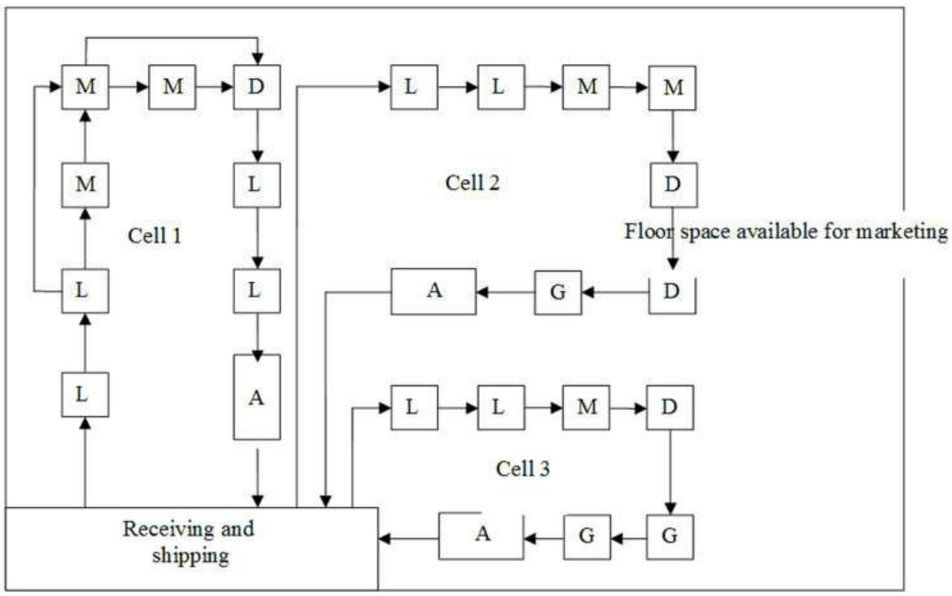


Figure: Cellular Manufacturing

Cellular manufacturing as shown in figure is a hybrid system which links the benefits of both job shop manufacturing and flow line manufacturing. It is more cost-effective to manufacture parts having medium volume and medium variety. Cellular manufacturing considerably reduces total manufacturing cost, time and area of manufacturing industries. Manufacturing industries who adopt cellular manufacturing get improvement in profit, productivity and production quality. Cellular manufacturing also helps manufacturers in defeating their competitors in global business scenario. If manufactures implement cellular manufacturing system in their manufacturing industries then they can fully satisfy their customers by selling high quality products quickly in reasonable price.

Cellular manufacturing can be implemented in four stages as per the following:

1) Cell formation: Grouping parts into part families and corresponding machines into machine cells by using the parts production process.
2) Intra-cell layout: Layout of machines within each cell.
3) Inter-cell layout: Layout of cells within the factory or shop floor.
4) Scheduling: Scheduling of jobs in each cell.

In cellular manufacturing, Objective of machine layout is to minimize the intra-cell movement of various parts within the cell and it is obtained by properly arranging machines within the cell. Objective of cell layout is to minimize the inter-cell movement within the floor space and it is achieved by properly arranging cells within the factory or shop floor.

Cell Formation (CF):

Cells are created in a workplace to facilitate flow. This is accomplished by bringing together operations or machines or people involved in a processing sequence of a products natural flow and grouping them close to one another, distinct from other groups. This grouping is called a cell. These cells are used to improve many factors in a manufacturing setting by allowing *one-piece flow* to occur. Some common formats of single cells are: the U-shape (good for communication and quick movement of workers), the straight line, or the L-shape. The number of workers inside these formations depend on current demand and can be modulated to increase or decrease production. For example, if a cell is normally occupied by two workers and demand is doubled, four workers should be placed in the cell. Similarly, if demand halves, one worker will occupy the cell. Since cells have a variety of differing equipment, it is therefore a requirement that any employee is skilled at multiple processes. The process of achieving a CMS is called cell formation (CF).

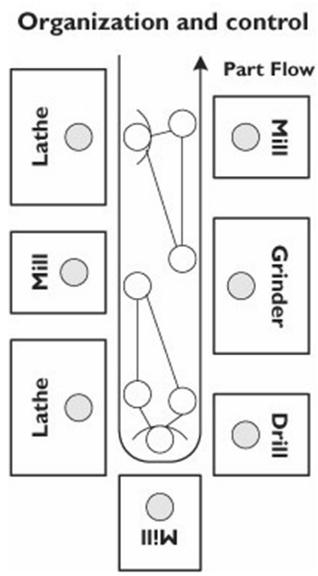


Figure: U-Shape One Piece Flow Cell

In addition to this, formation of cells consistently frees up floor space in the manufacturing/assembly environment (by having inventory only where it is absolutely required), improves safety in the work environment (due to smaller quantities of product/inventory being handled), improves morale (by imparting feelings of accomplishment and satisfaction in employees), reduces cost of inventory, and reducing inventory obsolescence. When formation of a cell would be too difficult, a simple principle is applied in order to improve efficiencies and flow, that is, to perform processes in a specific location and gather materials to that point at a rate dictated by an average of customer demand (this rate is called the takt time). This is referred to as the Pacemaker Process.

An office cell applies the same ideas: clusters of broadly trained cell-team members that, in concert, quickly handle all of the processing for a family of services or customers.

A virtual cell is a variation in which all cell resources are not brought together in a physical space. In a virtual cell, as in the standard model, team members and their equipment are dedicated to a family of products or services. Although people and equipment are physically dispersed, as in a job shop, their narrow product focus aims for and achieves quick throughput, with all its advantages, just as if the equipment were moved into a cellular cluster. Lacking the visibility of physical cells, virtual cells may employ the discipline of Kanban rules in order to tightly link the flows from process to process.

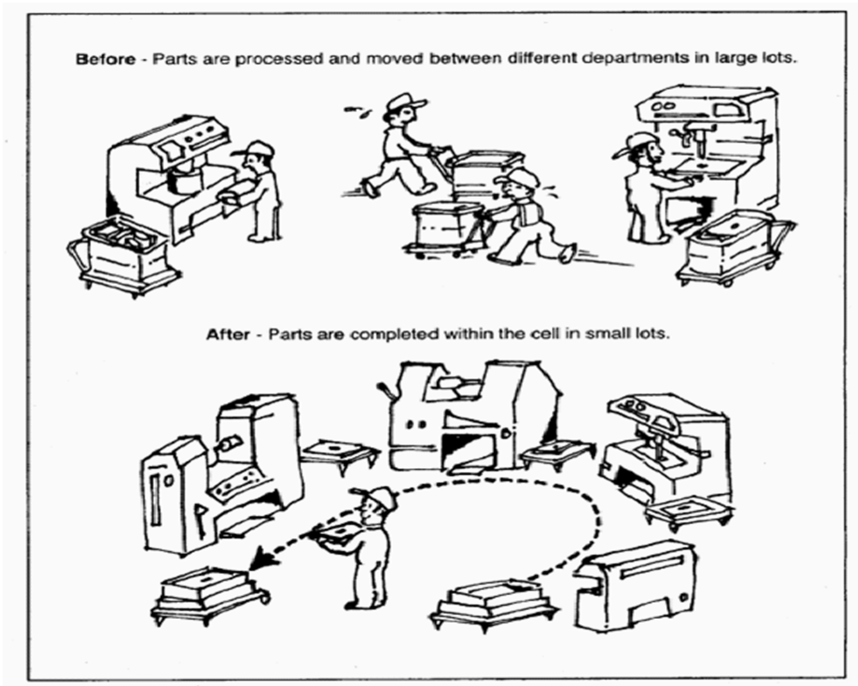


Figure: Example of Different Types of cell Formations

CM can be classified into three different environments (Droplet et al 1996):

1. Classical manufacturing cells,
2. Virtual manufacturing cells, and
3. Dynamic manufacturing cells.

Classical Manufacturing Cells:

A classical manufacturing system is machine intensive; most of the work content of operations is done by machines and not the workers. The workers' role is usually limited to loading and unloading work piece. Once cells are formed it is costly to rearrange the machines. As a result, frequent redesign is not an option. The design of a classical cell needs to be robust to handle changes in products and demand. If changes in product mix or demand are significant then it is necessary to redesign the cellular system. Redesign should be part of the overall cellular system planning.

Virtual Manufacturing Cells:

Virtual cellular manufacturing (VCM) is used in a system where it is infeasible to rearrange the machines or workstations, because the machines/workstations are relatively large in size. Each type of machine is spread throughout the facility and machines are grouped into cells on the assignment level and not necessarily the physical level as shown in Figure . In virtual cells the redesign of cells and product families are done with relative ease. As a facility grows to match the increase in demand, the efficiency of these virtual cells will increase and it might be possible to form classical cells. VCM often uses a just-in-time (JIT) approach to manufacturing, and there is little room for WIP(Work in Process) storage. Rearrangement of the cells is done with relative ease because the layout of the facility is not physically reconfigured. The material handling costs associated with virtual cells are high. If multiple machines of one type are needed they will be located in different areas of the facility, this could lead to confusion. Forming virtual cells will help reduce the confusion among planners and material handlers.

Dynamic Manufacturing Cells:

Dynamic CM is used in environments where product demand is unstable, and the workstations in the facility can be easily rearranged. This type of environment often exists in firms that do mostly subcontracting work. This environment is very labour intensive and it is easier (cheaper) to move machines than in VCM and classical CM. When a machine in a cell requires more capacity, it is cheaper to move a machine from another cell to the cell in question than to move the products. Inter-cell transfers often occur in the form of machine movement and not product movement. It is possible to eliminate excess material handling costs with this approach. Only one movement is taking place instead of several batches of a product being moved throughout a facility. Because of increasing variety of consumer goods and decrease in product life cycles, manufacturing organizations often face fluctuations in product demand and product mix leading to a dynamic or turbulent production environment. In dynamic production environments, a multi-period planning horizon is considered in which product mix and/or part demand rate in each period may be different such as seasonal products demand. It assumes that product mix and part demand is constant for the entire planning horizon. Product mix refers to a set of part types to be produced at each period. In dynamic environment, a planning horizon can be divided into smaller periods where each period has different product mix and demand requirements. Consequently, the formed cells in a current period may not be optimal and efficient for the next period. To overcome the disadvantages of traditional CMS, the concept of dynamic cellular manufacturing system (DCMS) is introduced. DCMS implicates to reconfiguration of manufacturing cells at each period. Reconfiguration involves swapping existing machines between cells called machine relocation; adding new machines to cells include machine replication, and removing existing machines from cells.

Combination Layout (Hybrid Layout):

- **i.** A combination of process and product layouts combines the advantages of both types of layouts. A combination layout is possible where an item is being made in different types and sizes.
- **ii.** Here machinery is arranged in a process layout but the process grouping is then arranged in a sequence to manufacture various types and sizes of products.
- **iii.** It is to be noted that the sequence of operations remains same with the variety of products and sizes.
- **iv.** For example, Supermarket layout are essentially process layouts, yet it find that most use fixed path material handling devices such as roller-type conveyors in stockroom and belt –type conveyors at the cash registers.
- **v.** Hospitals also use the basic process arrangement, although frequently patient care involves more of a fixed position approach, in which nurses, doctors, medicines and special equipment are brought to the patient.

vi. Faulty parts made in a product layout may require may require off-line reworking, which involves customized processing. Moreover, conveyors are frequently observed in both farming and construction activities.

<u>Advantages:</u>

1) Manufacture various types and size of products
2) Increase product quality
3) Flexible manufacturing
4) Advantages of both product and process layout example grocery store
5) Sequence of operation remains same with product mix

<u>Computerized Relative Allocation of Facilities Technique (CRAFT)</u>

CRAFT algorithm was originally developed by Armour and Buffa. It is an improvement algorithm. It starts with an initial layout and improves the layout by interchanging the departments pairwise so that the transport cost is minimized. The algorithm continues until not further interchanges are possible to reduce the transportation cost. The result given by CRAFT is not optimum in terms of minimum cost of transportation. But the result will be good and close to optimum in majority of applications. Hence, CRAFT is mainly a heuristic algorithm. Unfortunately, plant layout problem comes under combinatorial category. So, usage of efficient heuristic like CRAFT is inevitable for such problem.

CRAFT requirements

1) Initial layout
2) Flow data or Load summary
3) Cost per unit distance
4) Total number of departments
5) Fixed departments Number of such departments Location of those departments
6) Area of departments.

CRAFT Procedure:

The steps of CRAFT algorithm are summarized below:

Step1. Input:

a) Number of departments
b) Number of interchangeable departments
c) Initial layout
d) Cost matrix
e) Flow matrix (Load summary)
f) Area of departments.

Step 2. Compute centroids of departments in the present layout.

Step 3. Form distance matrix using the centroids.

Step 4. Given data on flow, distance and cost, compute the total handling cost of the present layout.

Step 5. Find all the possible pairwise interchanges of departments based on common border or equal area criterion. For each possibility, interchange the corresponding centroids and compute approximate costs.

Step 6. Find the pair of departments corresponding to the minimum handling cost from among all the possible pairs of interchanges.

Layout Planning and Analysis:

This is a procedure of making the layout of the plant or making improvement in the existing layout with the help of a number of tools and techniques. In this, a plan showing the position of machines, flow of work and material handling devices etc. is prepared to a scale on a drawing sheet or floor.The various tools and techniques used for the preparation of plant layout are described in short below:

(a) Flow process chart,
(b) Process flow diagram,
(c) Machine data card,
(d) Templates, and
(e) Scale models.

(a) Flow Process Chart:

This is a graphic representation of sequence of operation, transportation, inspection, delays and storage occurring during manufacture. This gives the information regarding distance moved and time required for various activities such as transportation, delay, inspection etc. This chart helps in determining hidden efficiencies in the processes and may suggest rearrangement of layout.This also points out elimination of unnecessary movement and processes

(b) Process Flow Diagram:

It is the diagram of building plan representing graphically the movement of materials on the drawing. With its help proper material handling arrangements can be made and it indicates long material hauls and back tracking of present layout, which thereby helps in improving the layout.

(c) Machine Data Cards:

These cards give complete specification of each machine to be installed such as output capacity, foundations, space needed, method of operation, maintenance and handling devices of machines etc.

(d) Templates:

After studying the flow process chart, process flow diagram and machine data cards, a floor plan is prepared by fixing the area occupied by each item to be erected in the shops. This floor plan is prepared at certain scale say 1 cm^2 = 1 m^2.

Now from thick sheets of paper or card board pieces are cut (known as templates) to represent various items which are to be housed in the plants, and are placed on the floor plans at suitable places. These templates are so arranged as to give best layout. The changes if any, required are made before making the actual layout drawing.

(e) Scale Models:

It is an improvement over the template method. In this tool, instead of templates, use of three dimensional scale models is made. These models may be of wood or metal and when used on a layout, series of additional information about the height and of the projected parts of the machines are obtained. This is similar to a child's doll house. This technique is useful for complex layout, requiring initially huge investment.

Methods and Production Flow Analysis & Minimization of Inter-Cell Movement.

Production Flow Analysis (PFA):

a. Developed by Burbridge in 1971, is a method for identifying part families and associated machine groupings that uses the information contained on production route sheets rather on part drawings.

b. Work parts with identical or similar routings are classified into part families.

c. PFA neither uses a classification and coding system nor part drawings to identify families.
d. It uses the information such as part number, operation sequence, lot size, etc., contained on the route sheet.
e. This method is based on the route sheet information and sometimes referred as the route sheet inspection method.

Steps Involved in PFA:

The following four steps are followed to carryout PFA:
(i) Data collection
(ii) Sortation of process routings
(iii) Preparation of PFA chart
(iv) Cluster analysis.

Step 1: Data collection:

1) The step in the PFA procedure is to collect the necessary data.
2) Route sheets of all the components to be manufactured in the shop are prepared.
3) Route sheet should contain the part number and operation sequence.
4) Other data that can be collected/obtained from route sheet/operation sheet include lot size, time standards and annual demand.

Step 2: Sortation of process routes:

1) The second step in the PFA is to arrange the parts into groups according to the similarity of their process routings.
2) A typical card format is required for organizing the data such as the part number, sequence of

code and lot size. A sortation procedure is used to arrange the parts into ‘packs’.

3) Pack is nothing but a group of parts with identical process routings. Some pack may even contain only one part number. A pack identification or letter is provided for each pack.

Step 3: PFA Chart:

1) A PFA chart is a graphical representation of the process used for each pack.
2) It is a tabulation of the process or machine code numbers for all of the part packs. Also known as ‘part-machine incidence matrix’ or ‘component-machine incidence matrix’.
3) The table below Illustrates a typical PFA chart having 7 machines (M1 to M7) and 9 parts (P1 to P9).

Machine	Parts								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
M1	1	1		1				1	
M2					1				1
M3			1		1				1
M4		1		1		1			
M5	1							1	
M6			1						1
M7		1				1	1		

4) In this matrix, the entries have a value x_{ij} = 1 or 0:
5) A value of x_{ij} = 1 indicates that the corresponding part i requires processing on machine j
6) x_{ij} = 0 indicates that no processing of component i is accomplished on machine j
7) However, in Table , the 0’s are indicated as blank (entry) entries for better clarity of the matrix.

Machine	Parts								
	P1	P2	P3	P4	P5	P6	P7	P8	P9
M1	1	1		1				1	
M2					1				1
M3			1		1				1
M4		1		1		1			
M5	1							1	
M6			1						1
M7		1				1	1		

Step 4: Cluster Analysis:

1) From the PFA chart, related grouping are identified and rearranged into a new pattern that brings together packs with similar machine sequences.
2) Table shows one possible rearrangement of the original PFA chart.
3) It is clear that for the PFA chart considered we have three part families and three machine cells, as shown below.

Machine	Parts								
	P1	**P8**	**P2**	**P4**	**P6**	**P7**	**P9**	**P3**	**P5**
M1	1	1	1	1					
M5	1	1							
M4			1	1	1				
M7			1		1	1			
M3							1	1	1
M6							1	1	
M2							1		1

Table : Rearranged PFA chart, indicating possible machine grouping

Part Families: Cell groups:

PF1 ={P1, P8}C,= { M1, M5}

PF2 ={P2, P4, P6}C2= {M4, M7}

PF3 ={P3, P5, P9}C3={M2, M3, M6}

Machine	Parts								
	P1	**P8**	**P2**	**P4**	**P6**	**P7**	**P9**	**P3**	**P5**
M1	1	1	1	1					
M5	1	1							
M4			1	1	1				
M7			1		1	1			
M3							1	1	1
M6							1	1	
M2							1		1

Advantages of PFA:

1) Parts classification and coding uses design data and the PFA uses manufacturing data (i.e., route sheet) to identify part families.
2) Due to this fact, as pointed out by Groover, PFA can overcome two possible anomalies that can occur in parts classification and coding.
3) First, parts whose basic geometries are quite different may nevertheless require similar or identical process routings.
4) Second, parts whose geometries are similar may nevertheless require process routings that are quite different.
5) Also PFA requires less time than a complete parts classification and coding procedure.

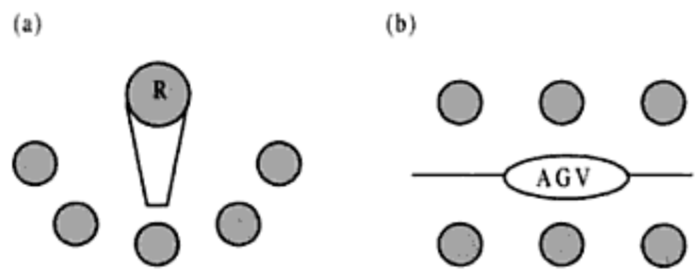
Disadvantages of PFA:

1) PFA does not provide any mechanism for rationalizing the manufacturing routings.
2) No consideration being given to routing sheet whether the routings are optimal or consistent or logical.

3) Process sequences from route sheets are prepared by different process planners, hence the routings may contain processing steps that are non- optimal, illogical and unnecessary.

Machine Cell Design and Layout:

1. Machine layout aims at determining the best arrangement of machines in each product cell.
2. Minimization of material handling cost is an often used objective in determining the layout of machines in a cell.
3. Constraints related to the availability of space, material handling system type and so on are considered.
    a. Type of operations and parts are not the only factors that impact the layout of machines.
    b. Type of material handling system to be used also needs to be considered;
4. Example, the articulated robot (R) in figure(a) implies a circular arrangement of machines.
5. If an AGV had been selected to tend the same machines, it would have been necessary to use the layout in figure(b).



Two step design of system

Goal of machine cell layout is to arrange the product or functional cells formed on the factory floor.

1) Determining the layout of machine cells involves locating the cells in order to minimize the total material handling cost subject to some constraints (e.g. shape of the facility).
2) If all cells were square in shape and of the same size, then the cell layout could be modeled as the quadratic assignment problem (QAP).
3) Cell layout problem can be viewed as a machine layout problem, where each machine represents a cell.
4) Though cellular manufacturing offers numerous benefits, it is not always implemented due to the following:
    - Parts and machines may not form mutually exclusive clusters.
    - The data required from the formation of cells might not be available.

Quantitative Analysis in Cellular Manufacturing:

Rank Order Clustering Method:

1) It also known as binary ordering algorithm (BOA), It is a simple algorithm used to form machine-part groups. it was Developed by J.R.King (1980).
2) It considers two data:

- Number of components and Component sequences. Based on the component sequences, a machine-part incidence matrix is developed.
- Rows of the machine component incidence matrix represent the machines which are required to process the components. Columns of the matrix represent the component numbers.

Concept:

Each row and each column of the matrix are considered as binary words. • Example, in a row if we have numbers (1 0 1 0 1), then the decimal equivalent is computed as follows:

Row decimal equivalent = (1× 24) +(0×23) + (1 × 22) + (0 × 21) + (1 × 20)
= 16 + 0 + 4 + 0+ 1
= 21

Concept:

If a column has the following entries from top to bottom, the decimal equivalent is computed as explained below:

Column entries = (11010)
Column decimal equivalent = (1 × 24) + (1 × 23) + (0 × 22) + (1 × 21) + (0 × 20)
= 16 + 8 + 0 + 2 + 0
= 26

Row with the largest decimal equivalent is considered to have the highest rank 1 among the rows. Column with the largest decimal equivalent is considered to have the highest rank among the columns.

Steps in ROC Algorithm:

The steps in ROC algorithm are given below:

- Step 0: Input: Total number of components, component sequences.
- Step 1: Form the machine-component incidence matrix using the component sequences.
- Step 2: Compute binary equivalent of each row.
- Step 3: Rearrange the rows of the matrix in rank wise (high to low from top to bottom).
- Step 4: Compute binary equivalent of each column and check whether the columns of the matrix are arranged in rank wise (high to low from left to right). If not, go to Step 7.
- Step 5: Rearrange the columns of the matrix rank wise and compute the binary equivalent of each row.
- Step 6: Check whether the rows of the matrix are arranged rank wise, If not, go to Step 3; otherwise, go to Step 7.
- Step 7: Print the final machine-component incidence matrix.

Hollier Method-Simple Problems:

Hollier Method 1:

The first method uses the sums of flow "From" and "To" each machine in the cell. The method can be outlined as follows:

1) Develop the From—To chart from part routing data. The data contained in the chart indicates number of part moves between the machines for workstations).

2) Determine the "From" and "To" sums for each machine. This is accomplished by summing all of the "From" trips and "To" trips for each machine (or operation).The "From" sum for a machine is determined by adding the entries in the corresponding row and the "To" sum is found by adding the entries in the corresponding column.
3) Assign machines to the cell based on minimum "From" or To sums. The machine having the smallest sum is selected. If the minimum value is a "To" sum, then the machine is placed at the beginning of the sequence. If the minimum value is a "From" sum, then the machine is placed at the end of the sequence. Tie breaker rules:
   - If a tie occurs between minimum. "To" sums or minimum "From" sums, then the machine with the minimum "From/To" ratio is selected.
   - If both "To" and "From" sums are equal for a selected machine, it is passed over and the machine with the next lowest sum is selected.
   - If a minimum "To" sum is equal to a minimum "From" sum, then both machines are selected and placed at the beginning and the end of the sequence respectively.

Reformat the From-To chart After each machine has been selected, restructure the From-To chart by eliminating the row and column corresponding to the selected machine and recalculate the "From" and "To" sums. Repeat steps 3 and 4 until all machines have been assigned.

Hollier Method 2:

This approach is based on the use of From/To ratios formed by summing the total flow from and to each machine in the cell. The method can be reduced to three steps:

1) Develop the From—To chart. This is the same step as in Hollier Method 1.

2) Determine the From/To ratio for each machine. This is accomplished by summing up all of the "From" trips and "To" trips for each machine (or operation). The "From" sum for a machine is determined by adding the entries in the corresponding row and the "To" sum is determined by adding the entries in the corresponding column. For each machine, the From/To ratio is calculated by taking the "From" sum for each machine and dividing by the respective "To" sum.

3) Arrange machines in order of decreasing From/To ratio. Machines with a high From/To ratio distribute work to many machines in the cell but receive work from few machines. Conversely machines with a low From/To ratio receive more work than they distribute. Therefore, machines are arranged in order of descending From/Ip ratio. That is, machines with high ratios are placed at the beginning of the work flow and machines with low ratios are placed at the end of the work flow. In case of a tie, the machine with the higher "From" value is placed ahead of the machine with a lower value.

Module – 2

Just–in–time (JIT) systems – Overview:

JIT (Just in Time)

1) Just in time technique can be risky, especially if it is not implemented correctly, but if the organization can do it in a right way then it can be most rewarding.

2) Just in time technique involves having item received in the organization just at the time when it is needed.

3) It can be risky because there may be so many variables which may not be always perfectly predictable.

4) **Just-in-time** (**JIT**) manufacturing, also known as **just-in-time** production or the Toyota Production System (TPS), is a methodology aimed primarily at reducing **times** within production system as well as response **times** from suppliers and to customers.

Figure: Just in Time (JIT)

Objectives of JIT

The objectives of JIT are to change the manufacturing system gradually rather than drastically:

1) To be more responsive to customers,
2) To have better communication among departments and suppliers,
3) To be more flexible,
4) To achieve better quality,
5) To reduce product cost.

Basic Principles of Just In Time:

To apply the method JIT then there are eight basic principles that should be considered in determining the manufacturing system strategies, namely:

1. Production in accordance with the Master Production Schedule orders

New manufacturing system will be operated to produce ascertained wait after a certain amount of incoming orders. The ultimate goal to produce finished goods on time and to the extent the amount you want to be consumed alone (Just in Time), for it would result in the production process as many times as needed and immediately sent to customers who need to avoid the stock and to reduce cost of storage (holding cost).

2. Production in small quantities

Production is carried out in a number of lots (Lot Size) are small to avoid planning and lead time are complex as well as in the production of large quantities. Flexibility of production activities will be done, because it is easier to make adjustments in the production plan especially against changes in market demand.

3. Reduce waste

Waste (waste) must be eliminated in every area of its existing operations. All use of input resources (materials, energy, machinery or working hours, etc.) should not exceed the minimum necessary to achieve the production target.

4. Improvement of product flow continuously.

The main aim is to eliminate processes that cause bottlenecks and unproductive all conditions (idle, delay, material handling, etc.) that can hinder the smooth flow of production.

5. Improvement of the quality of the product

Product quality is the goal of the application Just in Time production system. Here has always strived to achieve a state of “Zero Defect” by way of total control in every step of the process. All forms of deviation must be identified and corrected as early as possible.

6. Respect for all people / employees

With the method of Just in Time production system every worker will be given a full opportunity and authority to govern and make decisions whether a stream operation should be continued or terminated because of serious problems encountered in a particular work station.

7. Reduce all forms of uncertainty

Inventories are expected to anticipate the basic idea that fluctuating demand and any unexpected conditions, it will turn into waste if not used immediately. Similarly, recruitment of labor in large numbers in an uncontrolled manner as commonly encountered in the project activity will lead to waste if not used in time. Therefore, in planning and scheduling of production must be carefully designed and controlled.

8. Attention in the long run.

The seven principles of the implementation of Just in Time production system above is not a firm commitment that is applied in the short term, but it must be built on an ongoing basis and the commitment of all parties in the long run. In the short term, there is the possibility of application of Just in Time production system will only add to the cost of production following the consequences of the process of formation of a learning curve.

JIT as a Philosophy

- Elimination of waste:
- Continuous improvement
- Problems as opportunities
- Quality at the source
- Simplification
- Visual Control
- Focus on Customer Needs
- Production to Customer Demand
- Respect for Individual

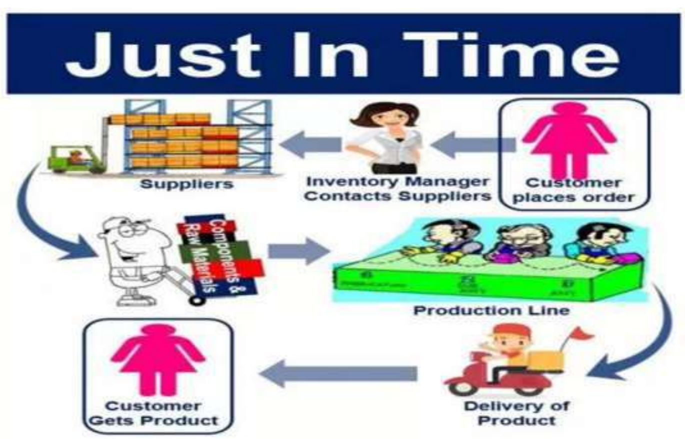


Figure: Example of JIT System

Elements of JIT:

1) Smooth flow of work
2) Elimination of waste
3) Continuous improvement
4) Eliminating anything that does not add value
5) Simple systems that are easy to manage
6) Use of product layouts to minimize moving materials and parts
7) Quality at the source

Advantages of JIT

1) There should be minimal amounts of inventory obsolescence, since the high rate of inventory turnover keeps any items from remaining in stock and becoming obsolete.
2) Since production runs are very short, it is easier to halt production of one product type and switch to a different product to meet changes in customer demand.
3) The very low inventory levels mean that inventory holding costs (such as warehouse space) are minimized.
4) The company is investing far less cash in its inventory, since less inventory is needed.
5) Fewer inventories can be damaged within the company, since it is not held long enough for storage-related accidents to arise. Also, having fewer inventories gives materials handlers more room to maneuver, so they are less likely to run into any inventory and cause damage.
6) Production mistakes can be spotted more quickly and corrected, which results in fewer products being produced that contain defects.

Disadvantages of JIT

1) A supplier that does not deliver goods to the company exactly on time and in the correct amounts could seriously impact the production process.
2) A natural disaster could interfere with the flow of goods to the company from suppliers, which could halt production almost at once.
3) An investment should be made in information technology to link the computer systems of the company and its suppliers, so that they can coordinate the delivery of parts and materials.
4) A company may not be able to immediately meet the requirements of a massive and unexpected order, since it has few or no stocks of finished goods.

Seven Wastes:

The seven wastes originated in Japan, where waste is known as **"Muda."** **"The seven wastes"** is a tool to further categorize **"Muda"** and was originally developed by Toyota's Chief Engineer Taiichi Ohno as the core of the Toyota Production System, also known as Lean Manufacturing. To eliminate waste, it is important to understand exactly what waste is and where it exists. While products significantly differ between factories, the typical wastes found in manufacturing environments are quite similar. For each waste, there is a strategy to reduce or eliminate its effect on a company, thereby improving overall performance and quality.

The seven wastes consist of:

1. Overproduction

Simply put, overproduction is to manufacture an item before it is actually required. Overproduction is highly costly to a manufacturing plant because it prohibits the smooth flow of materials and actually degrades quality and productivity. The Toyota Production System is also referred to as “Just in Time” (JIT) because every item is made just as it is needed. Overproduction manufacturing is referred to as “Just in Case.” This creates excessive lead times, results in high storage costs, and makes it difficult to detect defects. The simple solution to overproduction is turning off the tap; this requires a lot of courage because the problems that overproduction is hiding will be revealed. The concept is to schedule and produce only what can be immediately sold/shipped and improve machine changeover/set-up capability.

2. Waiting

Whenever goods are not moving or being processed, the waste of waiting occurs. Typically more than 99% of a product's life in traditional batch-and-queue manufacture will be spent waiting to be processed. Much of a product’s lead time is tied up in waiting for the next operation; this is usually because material flow is poor, production runs are too long, and distances between work centers are too great. Goldratt (Theory of Constraints) has stated many times that one hour lost in a bottleneck process is one hour lost to the entire factory's output, which can never be recovered. Linking processes together so that one feeds directly into the next can dramatically reduce waiting.

3. Transporting

Transporting product between processes is a cost incursion which adds no value to the product. Excessive movement and handling cause damage and are an opportunity for quality to deteriorate. Material handlers must be used to transport the materials, resulting in another organizational cost that adds no customer value. Transportation can be difficult to reduce due to the perceived costs of moving equipment and processes closer together. Furthermore, it is often hard to determine which processes should be next to each other. Mapping product flows can make this easier to visualize.

4. Inappropriate Processing

Often termed as "using a sledgehammer to crack a nut," many organizations use expensive high precision equipment where simpler tools would be sufficient. This often results in poor plant layout because preceding or subsequent operations are located far apart. In addition they encourage high asset utilization (over-production with minimal changeovers) in order to recover the high cost of this equipment. Toyota is famous for their use of low-cost automation, combined with immaculately maintained, often older machines. Investing in smaller, more flexible equipment where possible; creating manufacturing cells; and combining steps will greatly reduce the waste of inappropriate processing.

5. Unnecessary Inventory

Work in Progress (WIP) is a direct result of overproduction and waiting. Excess inventory tends to hide problems on the plant floor, which must be identified and resolved in order to improve operating performance. Excess inventory increases lead times, consumes productive floor space, delays the identification of problems, and inhibits communication. By achieving a seamless flow between work centers, many manufacturers have been able to improve customer service and slash inventories and their associated costs.

6. Unnecessary / Excess Motion

This waste is related to ergonomics and is seen in all instances of bending, stretching, walking, lifting, and reaching. These are also health and safety issues, which in today's litigious society are becoming more of a problem for organizations. Jobs with excessive motion should be analyzed and redesigned for improvement with the involvement of plant personnel.

7. Defects

Having a direct impact to the bottom line, quality defects resulting in rework or scrap are a tremendous cost to organizations. Associated costs include quarantining inventory, re-inspecting, rescheduling, and capacity loss. In many organizations the total cost of defects is often a significant percentage of total manufacturing cost. Through employee involvement and Continuous Process Improvement (CPI), there is a huge opportunity to reduce defects at many facilities.

Design and Improvement aspects of JIT:

JIT originated in Japan to maximize the output of a small amount of factories and resources. Along with then-novel practices like kanban and kaizen, JIT helped Japan rebuild their industrial manufacturing capacity after World War II. This method has gone on to influence American companies like Dell, Harley Davidson, and General Electric.

Housekeeping: physical organization and discipline

Invest in a design system. Organized and reusable design elements benefits just-in-time design in two ways:

1. Breaking designs down into independent components makes it easier to ship in smaller increments.
2. A shared set of design tools enables engineers to ship faster and opens the way to automation.

Lot sizes of one: the ultimate lot size and flexibility

Ship in the smallest increment possible. The “lot size” in manufacturing refers to the number of parts that get delivered as a group. For just-in-time design, delivering in smaller batches make it much easier to see the impact of each change.

Delivering in smaller increments also makes the feedback loops more forgiving. If one design doesn’t achieve the desired outcome, the next design is adjusted and improved.

Faster feedback cycles provide real-world insights on a regular basis. For instance, if a big redesign takes 6 months and only shipped when it’s 100% ready, the team is waiting 6 months to find out if their designs were effective. If the team breaks the work into 6 parts and delivers one part a month, they learn much sooner if their designs are effective and can adjust as they go.

Streamlining movements: smoothing materials handling

Get embedded in the team. Designers should use sprint planning, grooming, standup, and retro as opportunities to provide design to — and recieve feedback from — the rest of the team. Designs can take the form of written or verbal descriptions, not just wireframes and high-fidelity mockups.

Use a handoff tool. Tools like Zeplin, Abstract, or Invision Inspect make it much easier for designs to flow from designers to engineers.

Pull system—signal [kanban] replenishment/resupply systems.

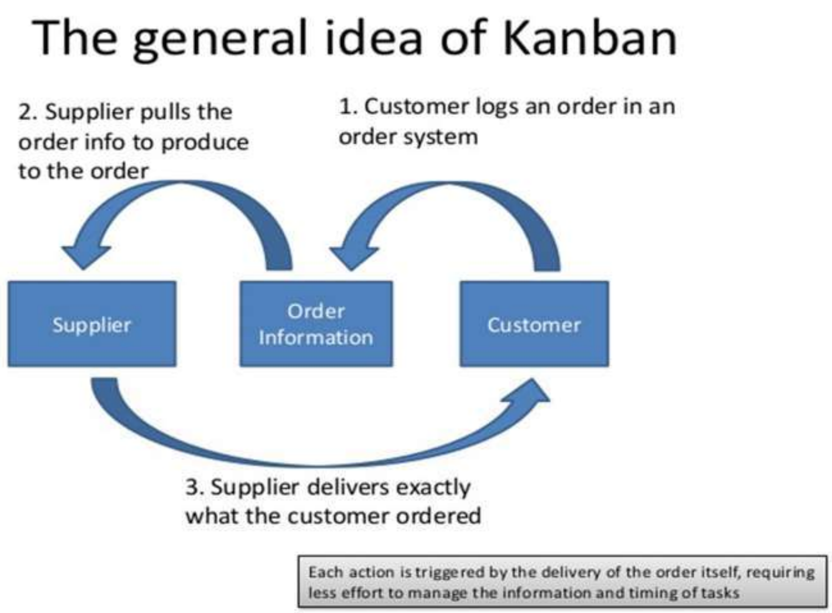
Only design what’s needed. Use constant communication between engineering and product partners to understand what your collaborators will need next. Then, plan on delivering *only what is needed*, and nothing more. Use the agile process — grooming, planning, and retro — to find any shortfalls or excesses.

Avoid creating a backlog of designs. Designs don't age well. In the time between finishing design and shipping code, it's likely that you'll learn something new that changes your understanding. If you're producing more design than can be implemented, focus more on the quality of each design.

Kanban systems–Definition and Principles:

Kanban (literally signboard or billboard in Japanese) is a scheduling system for lean and just-in-time (JIT) production. Kanban is a system to control the logistical chain from a production point of view, and is an inventory control system.

1) Kanban was developed by Taiichi Ohno, an industrial engineer at Toyota, as a system to improve and maintain a high level of production.
2) Problem areas are highlighted by reducing the number of kanban in circulation.
3) The Kanban Method is as an approach to incremental, evolutionary process and systems change for organizations. It uses a work-in-progress limited pull system as the core mechanism to expose system operation (or process) problems and stimulate collaboration to continuously improve the system.
4) Visualization is an important aspect of Kanban as it allows understanding the work and the workflow.



The basic principles Kanban System:

1. Start with existing process
2. The Kanban method does not prescribe a specific set of roles or process steps.
3. The Kanban method starts with existing roles and processes and stimulates continuous, incremental and evolutionary changes to the system. The Kanban method is a change management method.

4. Agree to pursue incremental, evolutionary change
5. Respect the current process, roles, responsibilities and titles
6. Leadership at all levels
7. Acts of leadership at all levels in the organization, from individual contributors to senior management, are encouraged.

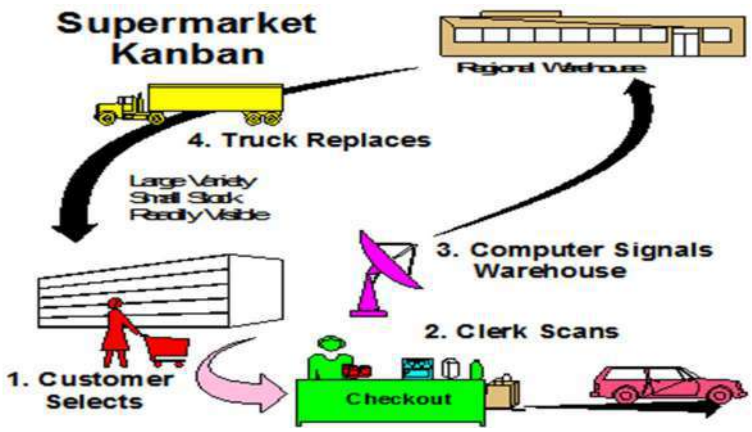


Figure: Example of kanban scheduling of Super Market

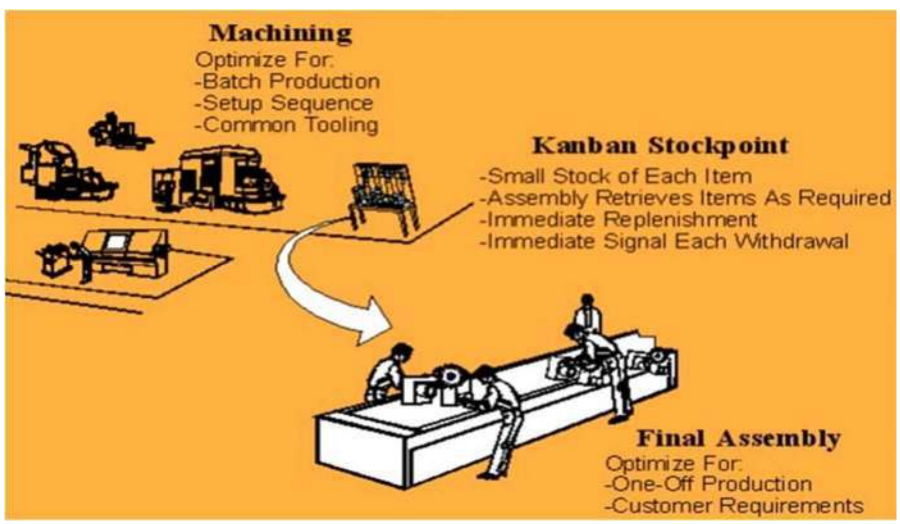
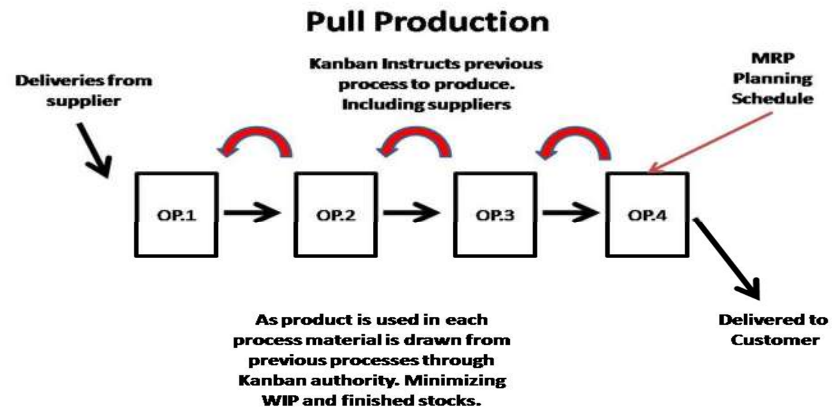


Figure: Example of kanban System in Manufacturing Environment (Assembly Line)

Types of Kanban systems:

In a kanban system, the workstations communicate with each other through their cards, where each container has a kanban associated with it. Economic Order Quantity is important. The two most important types of kanban are:

Production (P) Kanban: A P-kanban, when received, authorizes the workstation to produce a fixed amount of products. The P-kanban is carried on the containers that are associated with it.



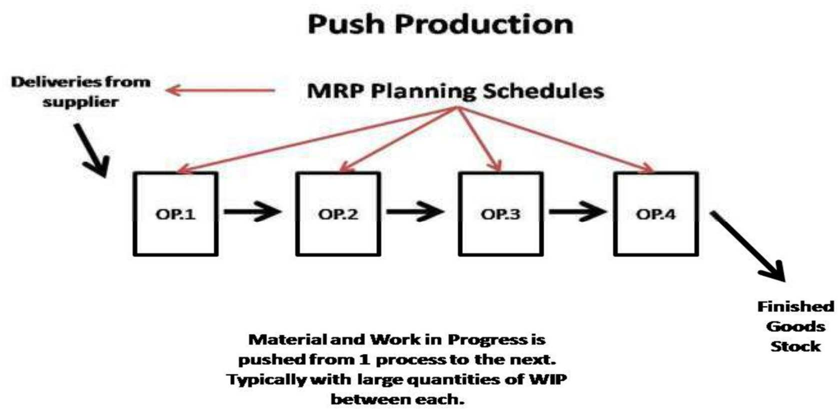
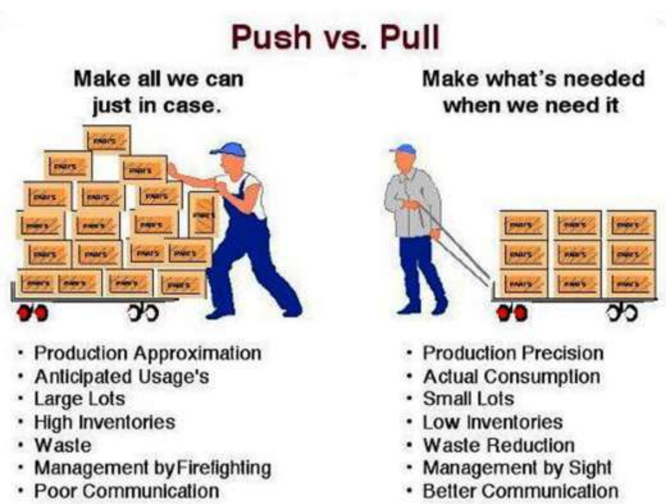


Figure: Example of Production (Pull & Push) Kanban



Transportation (T) Kanban: A T-kanban authorizes the transportation of the full container to the downstream workstation. The T-kanban is also carried on the containers that are associated with the transportation to move through the loop again.

Kanban is a scheduling system for lean manufacturing and just-in-time manufacturing (JIT). Taiichi Ohno, an industrial engineer at Toyota, developed kanban to improve manufacturing efficiency. Kanban is one method to achieve JIT. The system takes its name from the cards that track production within a factory. For many in the automotive sector, kanban is known as the "Toyota nameplate system" and as such the term is not used by some other automakers. Toyota, for example, has six simple rules, and close monitoring of these rules is a never-ending task, thereby ensuring that the kanban does what is required.

Toyota's Six Rules

Toyota has formulated six rules for the application of kanban:

1) Each process issues requests (kanban) to its suppliers as it consumes its supplies.
2) Each process produces according to the quantity and sequence of incoming requests.
3) No items are made or transported without a request.
4) The request associated with an item is always attached to it.
5) Processes must not send out defective items, to ensure that finished products will be defect-free.
6) Limiting the number of pending requests makes the process more sensitive and reveals inefficiencies.

<u>Kanban (cards):</u>

Kanban cards are a key component of kanban and they signal the need to move materials within a production facility or to move materials from an outside supplier into the production facility. The kanban card is, in effect, a message that signals a depletion of product, parts, or inventory. For more production, and the kanban card signals demand for more product so kanban cards help create a demand-driven system. It help to lower inventory levels, helping companies implementing such systems be more competitive.

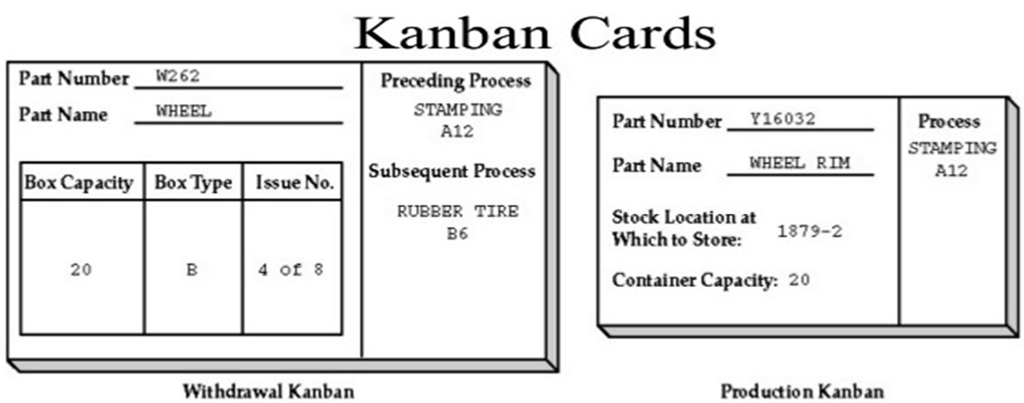


Figure: Kanban Card

Single Card/One Card Kanban:

The "one-card" is the simplest implementation of kanban systems. This approach is used when the upstream and downstream workstations (respectively, the preceding and succeeding processes) are physically close to each other, so they can share the same stock buffer. The card is called "Production Order Kanban" (POK). The stock buffer acts either as the outbound buffer for the first (A) workstation or as the inbound buffer for the second (B) workstation. A schematic diagram of a one-card system is shown in Figure.

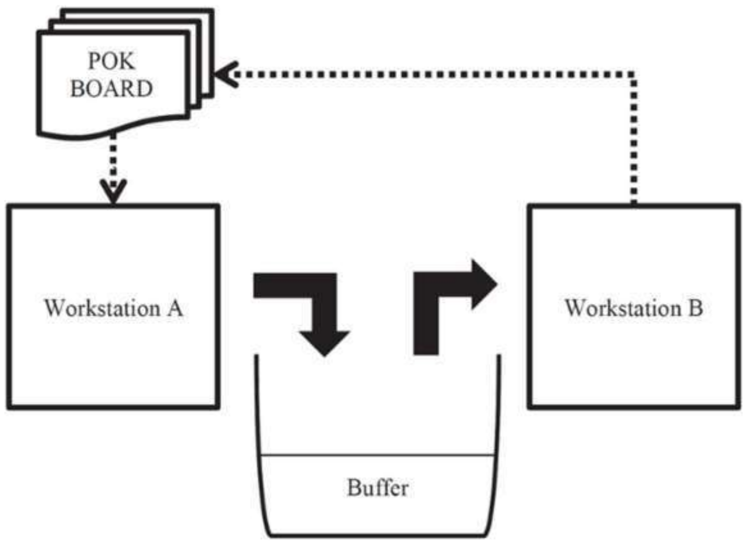


Figure. A One-Card Kanban System

Here, each container (the JIT unit load) has a POK attached, indicating the quantity of a certain material contained, along with eventual complementary information. The POK also represents a production order for the Workstation A, indicating to replenish the container with the same quantity. When a B operator withdraws a container from the buffer, he removes the POK from the container and posts it on a board. Hence, An operator knows that one container with a specific part-number must be replenished in the stock buffer.

Two card Kanban:

In the two-card system, each workstation has separate inbound and outbound buffers1, 2. Two different types of cards are used: Production Order Kanbans (POK) and Withdrawal Kanbans (WK). A WK contains information on how much material (raw materials / semi-finished materials) the succeeding process should withdraw. A schematic diagram of a two-card system is shown in Figure.

Each work-in-progress (WIP) container in the inbound buffer has a WK attached, as well as each WIP in the outbound buffer has a POK. WK and POK are paired, i.e. each given part number is always reported both in n POK and n WK. When a container is withdrawn from the inbound buffer, the B operator posts the WK on the WK board. Then, a warehouse-keeper operator uses the WK board as a picking list to replenish the inbound buffer: he takes the WK off the board and look for the paired POK in the outbound buffer. Then, he moves the corresponding quantity of the indicated material from the A outbound to the B inbound buffer, while exchanging the related POK with the WK on the container, restoring the initial situation. Finally, he posts the left POK on the POK board. Hence, like in the previous scenario, A workstation operator knows that one container of that kind must be replenished in the outbound stock buffer. The effectiveness of this simple technique – which was significantly influenced by the policy followed to determine the kanban processing order, in the boards.

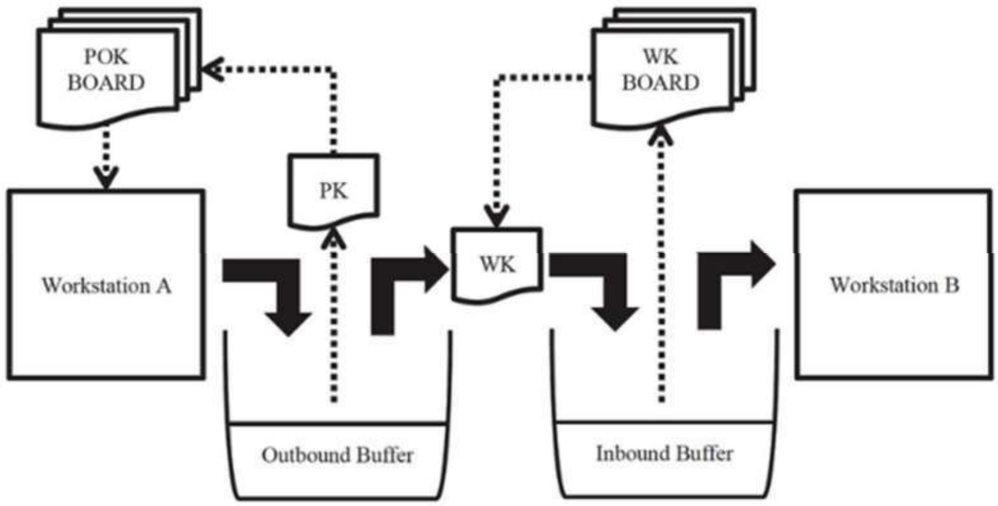


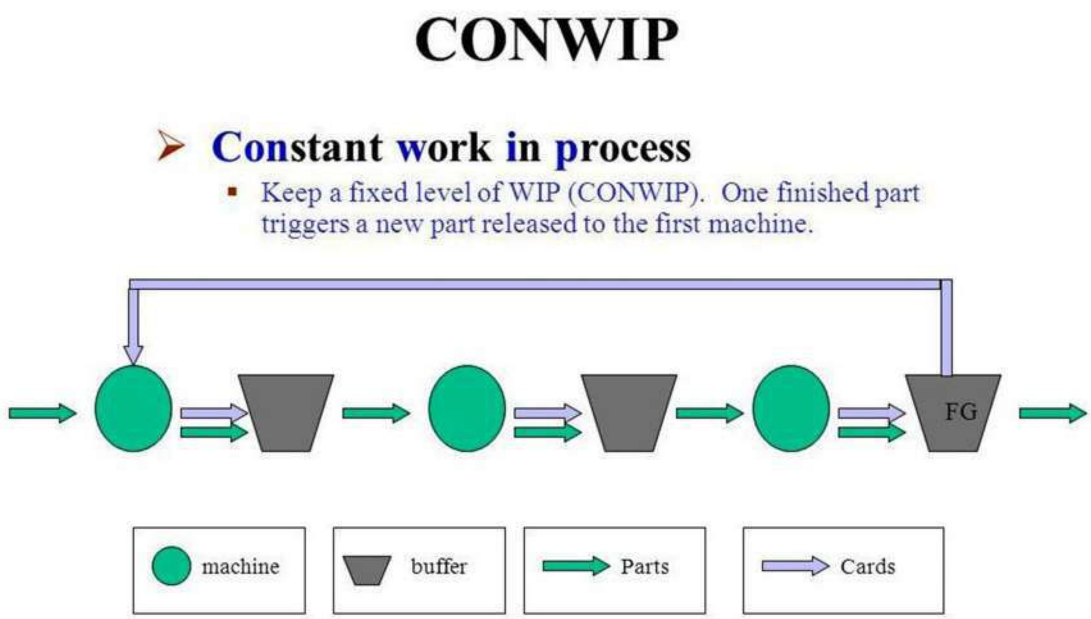
Figure. A Two-Card Kanban System

<u>Alternative approaches of JIT:</u>

1) **Constant Work–in–Process (CONWIP)**
2) **POLCA**
3) **Just in Sequence**
4) **Theory of Constraints**

Constant Work–in–Process (CONWIP)

Many alternatives to JIT have been proposed since TPS appeared in Western countries. One of the most famous JIT-derivative approaches is CONWIP (CONstant Work-In-Process). **CONWIP**, standing for *Constant Work In Progress* and developed by Mark Spearman and Wallace Hopp in 1990. it, tries to mix push and pull approaches: it schedules tasks for each station – with a push approach – while production is triggered by inventory events, which is a pull rule. Thus, CONWIP is card-based, as kanban systems, but cards do not trigger the production of a single component in the closest upward workstation; conversely, cards are used to start the whole production line, from beginning downwards. Then, from the first workstation up to the last one, the process is push-driven; materials are processed as they get to an inbound buffer, notwithstanding the stock levels. Only the last workstation has a predetermined stock level, similar to the JIT outbound buffer. All queues are managed through a FIFO policy. In order to have a leveled production rate and to avoid production spikes or idle times, the system is calibrated on the slowest workstation, the bottleneck. Results from simulations showed 2 that CONWIP could grant shorter lead times and more stable production rate if compared to Kanban; however, it usually needs a higher WIP level. A CONWIP system is also easier to implement and adjust, since it has only one card set.



Comparison Constant Work–in–Process (CONWIP) with Kanban system:

1) CONWIP systems immediately react to increases in customer demand. As customers increase the rate at which jobs are withdrawn , the high demand jobs are released into the system.
2) CONWIP systems do not need the setup and maintenance of Kanban cards and containers for each part type.
3) CONWIP systems react well for highly variable part mix demand while maintaining relatively constant levels of inventory.
4) CONWIP systems are differs from Kanban all WIP is aggregated and treated as a whole.
5) CONWIP systems are similar to kanban system in goal of maintaining constant level of work-in-process.
6) Hence a CONWIP card is like a kanban card, except the part type gets assigned only on its way back when it meets the most urgent demand in the backlog.

POLCA:

Another alternative technique mixing push and pull system is the POLCA (Paired-Cell Overlapping Loops of Cards with Authorization), which stands at the base of the Quick Response Manufacturing (QRM) approach, proposed in 19981. QRM aims to minimize lead times rather than addressing waste reduction, as TPS does. A series of tools, such as manufacturing critical-path time, cellular organization, batch optimization and high level MRP, are used to minimize stock levels: the lesser is the lead time, the lesser is the on-hand inventory. Likewise CONWIP, POLCA handles WIP proliferation originating from multiple products, since it does not require each station to have a base stock of each component. At first, an MRP-like algorithm (called HL/MRP) creates some “Release Authorization Times”. That means that the HL/MRP system defines when each cell may start each job, as MRP defines the “Start Dates”. However, differently from a standard push system - where a workstation should process the job as soon as possible - POLCA simply authorizes the possibility to start the job. Analogously to CONWIP and Kanban, POLCA uses production control cards in order to control material flows. These cards are only used between, and not within, work cells. Inside each work cell, material flows resemble the CONWIP approach. On top of this, the POLCA cards, instead of being specifically assigned to a product as in a Kanban system, are assigned to pairs of cells. Moreover, whereas a POK card is an inventory replenishment signal, a POLCA card is a capacity signal. If a card returns from a downstream cell, it signals that there is enough capacity to process a job. Thus, the preceding cell will proceed only if the succeeding cell has available production capacity. According to some authors 2 a POLCA system may overcome the drawbacks of both standard MRPs and kanban systems, helping in managing both short-term fluctuation in capacity (slowdowns, failures, setups, quality issues) and reducing unnecessary stocks, which is always present in any unlevelled replenishment system – i.e. where heijunka condition is not met.

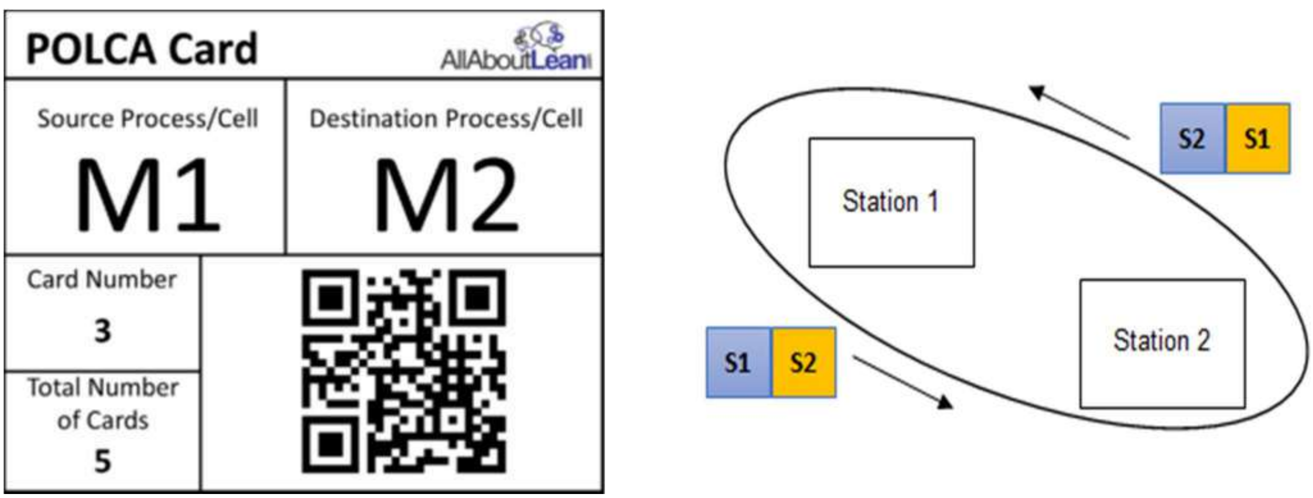


Figure: POLCA Card & POLCA Diagram

Just in Sequence:

The Just in Sequence approach is an evolution of JIT, which embeds the CONWIP idea of mixing push/requirement and pull/replenishment production management systems. The overall goal of JIS is to synchronize the material flow within the supply chain and to reduce both safety stocks and material handling. Once the optimal production sequence is decided, it is adopted all along the process line and up to the supply chain. Thus, the suppliers are asked to comply not only to quantity requirements but also to the product sequence and mix, for a certain period of time. In this case the demand must be stable, or a frozen period should be defined (i.e. a time interval, prior to production, in which the demand cannot be changed)1. Clearly, when the demand mix significantly changes, the sequence must be re-computed, similarly to what happens in MRP. This makes the JIS system less flexible compared to JIT. Research results2 proved that, applying some techniques to reduce unsteadiness – such as flexible order assignment or mixed bank buffers – the sequence can be preserved with a low stock level. Thanks to ad-hoc rescheduling points the sequence can be propagated downstream, reducing the impact of variability.

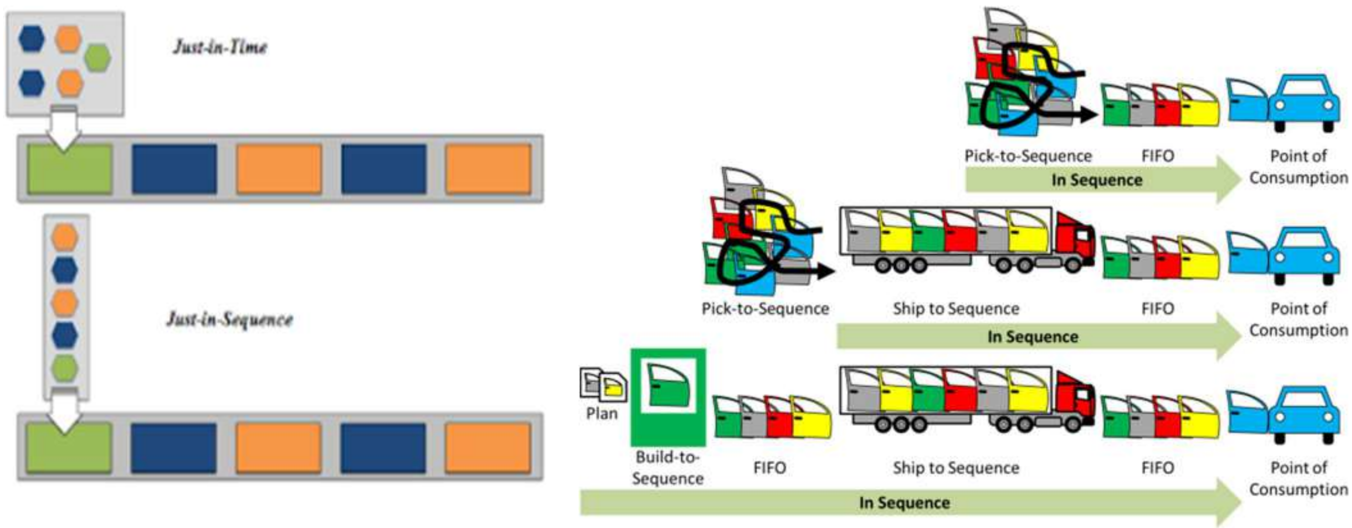


Figure: Just in Sequence

Theory of Constraints:

Leveraging on the common idea that "a chain is no stronger than its weakest link", the Israeli physicist E.M. Goldratt firstly introduced the Theory of Constraints (TOC) in his most famous business novel "the Goal"1. Looking to a production flow-shop as a chain, the weakest link is represented by the line bottleneck. Compared to the TPS approach of reducing wastes, this approach is focused on improving bottleneck operations, trying to maximize the throughput (production rate), minimizing inventory and operational expenses at the same time.

Its implementation is based on a loop of five steps:

1) Constraint identification;
2) Constraint optimization;
3) Alignment of the other operations to the constraint optimization;
4) Elevation of the constraint (improving throughput);
5) If the constraint after the previous 4 steps has moved, restart the process.

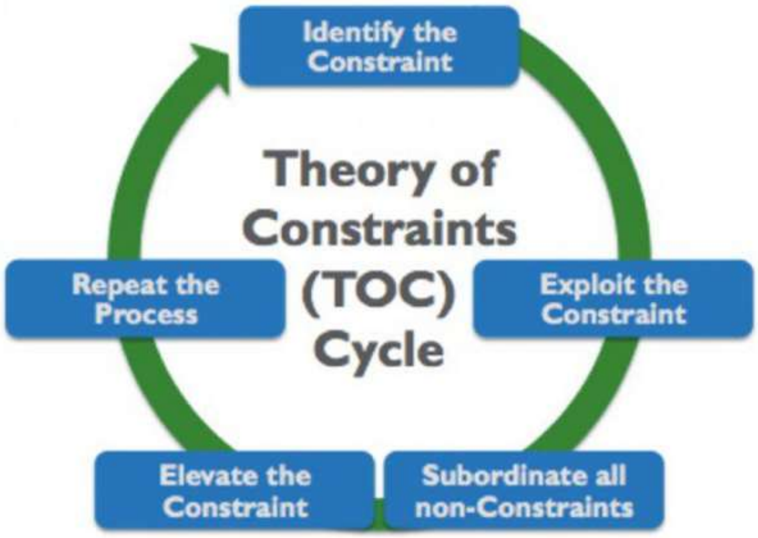


Figure: Theory of Constraints Cycle

Again, Deming's concept of "improvement cycle" is recalled. However, improvements are only focused on the bottleneck, the Critical Constraint Resource (CCR), whereas in the Lean Production's Kaizen approach bottom-up, an improvement may arise wherever wastes are identified; moreover, improvements only aim to increase throughput. It is though noticeable that the author includes, as a possible throughput constraint, not only machinery problem but also people (lack of proper skills) and policies (bad working). To this extent, Goldratt coined the "Drum-Buffer-Rope" (DBR) expression: the bottleneck workstation will define the production takt-time, giving the beat as with a drum. The remaining upstream and downstream workstations will follow this beat. This requires the drum to have an optimized schedule, which is imposed to all the production line. Thus, takt-time is not defined from the final demand anymore, but is set equal to the CCR minimal cycle time, given that the bottleneck capacity cannot be overcome. A "buffer" stock is only placed before the CCR, assuring that no upward issue could affect the process pace, reducing line throughput. This helps in reducing the inventory level in comparison to replenishment approaches, where buffers are placed among all the workstations. Eventually, other stock buffers may be placed in few synchronization points in the processes, besides the final product warehouse, which prevents stock-outs due to oscillating demand. The "rope" represents the job release authorization mechanism: a CONWIP approach is used between the CCR and the first phase of the process. Thus, the advanced entrance of a job in the system is proportional to the buffer size, measured in time. Failing to comply with this rule is likely to generate too high work-in-process, slowing down the entire system, or to generate a starvation condition on the CCR, with the risk of reducing the throughput. Several authors2, 3, 4] analyzed the DBR rule in comparison to planning with mathematical linear programming techniques. Results on the most effective approach are controversial.

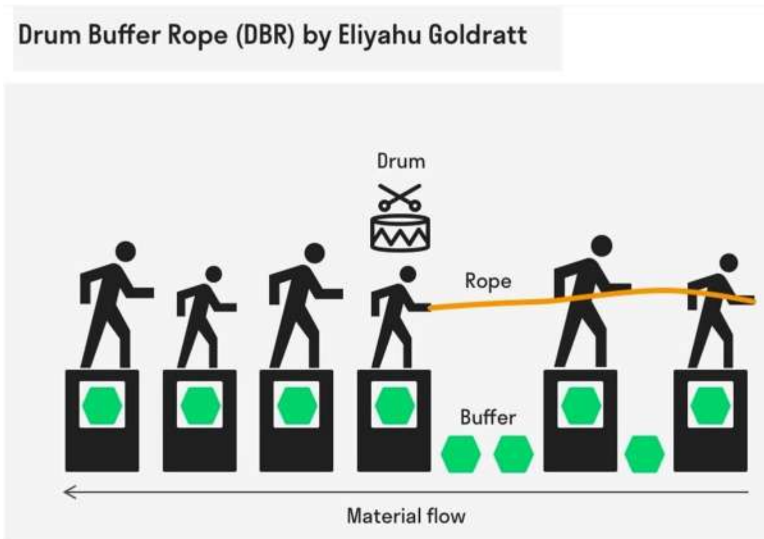


Figure: "Drum-Buffer-Rope" (DBR) expression in TOC

<u>Standard approaches to manage the kanban board:</u>

From the previously described procedure, it is clear that the each workstation bases its production sequence on kanban cards posted on the POK board. In literature, few traditional ways to manage the board are reported: each of them is quite easy to implement and does not require significant investments in technology or other expensive assets.

The most commonly used policy1 requires having a board for each station, and this should be managed as a single First-In-First-Out (FIFO) queue. The board is usually structured as one vector (one column, multiple rows): POK are posted on the board in the last row. Rows are grouped in three zones (red/yellow/green) which indicate three levels of urgency (respectively, high/medium/low). Kanban are progressively moved from the green to the red zone and the workstation operator will process the topmost kanban. If a kanban reaches the red rows, it means that the correspondent material is likely to be requested soon, by the succeeding process. Thus, it should be urgently replenished in the outbound buffer, in order to avoid stock-outs.

Although this policy does not rely on any optimized procedure, it may ensure a leveled production rate in each workstation, given the fact that other TPS pillars are implemented, e.g. setup time reduction and mixed model scheduling. Indeed, if the final downstream demand is leveled, the production plan of the workstations will be leveled as well. Clearly, this policy is vulnerable to high setup times and differences among workstations cycle times: in this latter case, indeed, the ideal jobs sequence for a workstation may be far from optimal for the preceding. It is noticeable that the colored zones on the board only provide a visual support for the operators and do not influence the jobs processing order.

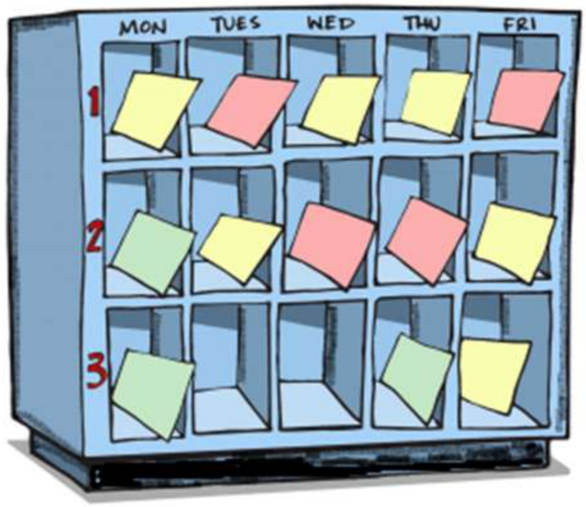


Figure: Heijunka box

A heijunka box is a sort of enhanced kanban board: it still acts as a visual scheduling tool to obtain production leveling at the workstations. However, differently from the traditional board, it manages to keep evidence of materials distinctions. Usually, it is represented as a grid-shaped wall schedule. Analogously to the simpler board, each row represents a time interval (usually, 30-60 minutes), but multiple columns are present, each one associated to a different material. POKs are placed in the so-called "pigeon-holes" within the box, based on number of items to be processed in the job and on the material type. Workstation operators will process all the kanban placed in the current period row, removing them from the box. Hence, heijunka box not only provides a representation for each job queued for production, but for its scheduled time as well, and allows operators to pursue production leveling when inserting new POKs in the boxes.

Three-Bin System:

An example of a simple kanban system implementation is a "three-bin system" for the supplied parts, where there is no in-house manufacturing. One bin is on the factory floor (the initial demand point), one bin is in the factory store (the inventory control point), and one bin is at the supplier. The bins usually have a removable card containing the product details and other relevant information, the classic kanban card. When the bin on the factory floor is empty (because the parts in it were used up in a manufacturing process), the empty bin and its kanban card are returned to the factory store (the inventory control point). The factory store replaces the empty bin on the factory floor with the full bin from the factory store, which also contains a kanban card. The factory store sends the empty bin with its kanban card to the supplier. The supplier's full product bin, with its kanban card, is delivered to the factory store; the supplier keeps the empty bin. This is the final step in the process. Thus, the process never runs out of product and could be described as a closed loop, in that it provides the exact amount required, with only one spare bin so there is never oversupply.

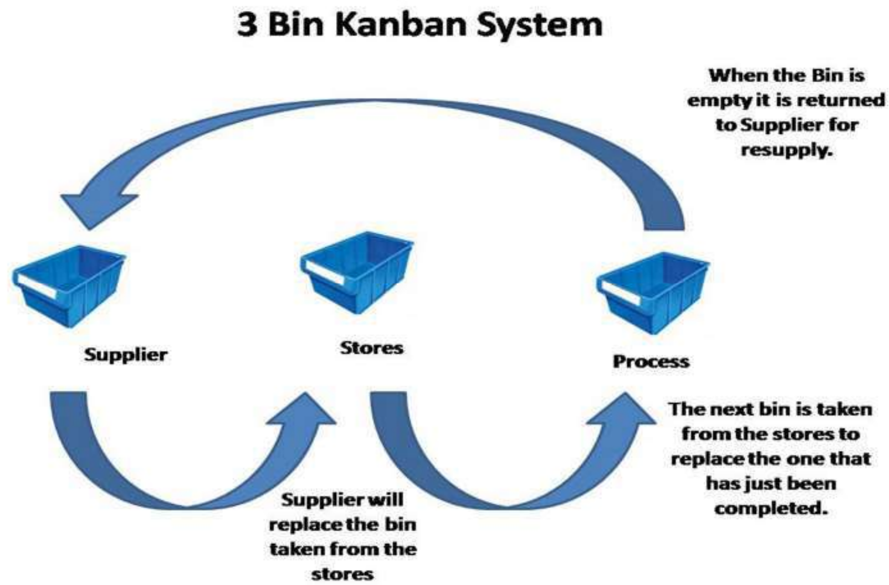


Figure: Three Bin Kanban System

Electronic Kanban:

Many manufacturers have implemented electronic kanban (E-kanban) systems. These help to eliminate common problems such as manual entry errors and lost cards. E-kanban systems can be integrated into enterprise resource planning (ERP) systems, enabling real-time demand signaling across the supply chain and improved visibility. Data pulled from E-kanban systems can be used to optimize inventory levels by better tracking supplier lead and replenishment times. E-kanban is a signaling system that uses a mix of technology to trigger the movement of materials within a manufacturing or production facility. Electronic Kanban differs from traditional kanban in that it uses technology to replace traditional elements such as kanban cards with barcodes and electronic messages such as email or Electronic data interchange.

Figure: Electronic kanban

Advantages of Kanban:

1) Optimize inventory and reduce product obsolescence (outdated)
2) Reduce wastes and scraps
3) Provide flexibility in production
4) Increased output (productivity)
5) Reduce total cost
6) Improve production flow
7) Place control at the operational level
8) Improve responsiveness to change demand
9) Better machine utilization
10) Quickly improvement for factory control and work in process (WIP) reduction efforts
11) Reduce or eliminate queue.

Disadvantages of Kanban:

1) It is less effective in shared- resource situation.
2) Surge in mix or demand cause problem because kanban assume stable repetitive production plan.
3) Poor quality in term of scrap and rework also effect its good functioning
4) Kanban does not eliminate variability, so unpredictable and lengthy down time could disturb the whole system.
5) It is not suited for manufacturing environment with short production run.
6) Kanban not suited for highly variable demand, multi product and good quality product.
7) A break down in kanban system can result in the entire line shutting down.

Module – 3

Synchronous manufacturing (Theory of Constraints)

Theory of Constraints (Definition):

Constraints:

A constraint is anything that prevents the system from achieving more of its goal. There are many ways that constraints can show up, but a core principle within TOC is that there are not tens or hundreds of constraints. There is at least one and at most a few in any given system. Constraints can be internal or external to the system. An internal constraint is in evidence when the market demands more from the system than it can deliver. If this is the case, then the focus of the organization should be on discovering that constraint and following the five focusing steps to open it up (and potentially remove it). An external constraint exists when the system can produce more than the market will bear. If this is the case, then the organization should focus on mechanisms to create more demand for its products or services. Types of (internal) constraints are given below;

Equipment: The way equipment is currently used limits the ability of the system to produce more salable goods/services.

People: Lack of skilled people limits the system. Mental models held by people can cause behavior that becomes a constraint.

Policy: A written or unwritten policy prevents the system from making more.

The concept of the constraint in Theory of Constraints differs from the constraint that shows up in mathematical optimization. In TOC, the constraint is used as a focusing mechanism for management of the system. In optimization, the constraint is written into the mathematical expressions to limit the scope of the solution (X can be no greater than 5). Organizations have many problems with equipment, people, policies, etc. (A breakdown is just that a breakdown and is not a constraint in the true sense of the TOC concept). The constraint is the thing that is preventing the organization from getting more throughputs (typically, revenue through sales).

Theory of Constraints (TOC):

The theory of constraints (TOC) is a relatively recent development in the practical aspect of making organizational decisions in situations where constraints exist. Dr. Eliyahu M. Goldratt first described the theory in his novel, The Goal, which was published in the year 1992. TOC is a systems approach based on the assumption that every organization has at least one factor that inhibits the organization's ability to meet its objectives. The normal objective for a business is to maximize profit. The TOC emphasizes the maximization of profit by assuring that the factor that limits production is used most efficiently. Manufacturing philosophy based on TOC focuses on change at three levels (the 3Ms): the Mindset of the organization, the Measures that drive the organization and the Methods employed within the organization.

The TOC concept of Throughput-world thinking (TWT) creates a mindset that the goal of a firm is 'to make more money' (not to save money or reduce costs). This mindset further stipulates that certain necessary conditions should never be violated when making decisions in a firm in order to achieve the profit-goal. Two such important conditions generally discussed in TOC literature are (a) provide a satisfying work environment to employees, and (b) provide satisfaction to the market. The most basic statement of TOC is that; (i) Systems are defined by a single goal & (ii) The output of a system is limited by a constraint.

Under TOC, the objective is to maximize the throughputs while minimizing operating expenses for labor, sales, administration and simultaneously minimizing investment outlays for inventory, plant and equipment. For most business organizations the goal is to make money now as well as in the future. The theory of constraints (TOC) adopts the common idiom "A chain is no stronger than its weakest link" as a new management paradigm. This means that processes, organizations, etc., are vulnerable because the weakest person or part can always damage or break them or at least adversely affect the outcome. The analytic approach with TOC comes from the contention that any manageable system is limited in achieving more of its goals by a very small number of constraints, and that there is always at least one constraint. Hence the TOC process seeks to identify the constraint and restructure the rest of the organization around it, through the use of five focusing steps. A factor that limits a company's ability to achieve more of its goal is referred to as a "constraint". Businesses need to identify and manage constraints. TOC is a management philosophy that focuses the organizations scarce resources on improving the performance of the true constraint, and therefore the bottom line of the organization. Goldratt uses a chain analogy to help illustrate why this is an effective way to get immediate results. A manufacturing company can be thought of as a chain of dependent events that are linked together like a chain. The activities that go on in one 'link' are dependent upon the activities that occur in the preceding 'link'. TOC says that management needs to find the weak link in the chain since "a chain is only as strong its weakest link." Thus, a company should focus on "chain strength" (not link weight) by working to strengthen the weakest link i.e. the constraint.

Five-Step Process of On-Going Improvement:

The underlying premise of theory of constraints is that organizations can be measured and controlled by variations on three measures: throughput, operational expense, and inventory. Throughput is the rate at which the system generates money through sales. Inventory is all the money that the system has invested in purchasing things which it intends to sell. Operational expense is all the money the system spends in order to turn inventory into throughput. Theory of constraints is based on the premise that the rate of goal achievement by a goal-oriented system (i.e., the system's throughput) is limited by at least one constraint. The argument by reduction absurdum is as follows: If there was nothing preventing a system from achieving higher throughput (i.e., more goal units in a unit of time), its throughput would be infinite which is impossible in a real-life system. Only by increasing flow through the constraint can overall throughput be increased. Before the goal itself can be reached, Necessary Conditions must first be met. This typically includes safety, quality, legal obligations, etc. For most businesses, the goal itself is to make money. However, for many organizations and non-profit businesses, making money is a necessary condition for pursuing the goal. Whether it is the goal or a necessary condition, understanding how to make sound financial decisions based on throughput, inventory, and operating expense is a critical requirement. To manage constraints Goldratt proposes five-step process of on-going improvement. The steps in this process are:

1) **Identify:** In order to manage a constraint, it is first necessary to identify the system's constraints that are just the ones that really limits system progress towards the goal.
2) **Exploit:** After identification of the constraints it is decided how to manage the constraints within the system. They are managed in such a way that they just provide what is needed to match the output of the constrained resources and not allowed to supply more output than is needed because doing so closure to the goal is not achieved. It is always desirable to focus on how to get more production within the existing capacity limitations.
3) **Subordinate:** Everything else is subordinated to the above decision in Step ii. Since the constraints keep away from moving towards the goal, all of the resources that can assist in breaking them are applied. Practically in all cases their limiting impact can be reduced or eliminated. It is necessary to prevent the materials needed next from waiting in a queue at a non-constraint resource.
4) **Elevate:** The system's constraints are elevated. A constraint will no longer be a constraint, at some point if continuous work is done towards breaking a constraint. The constraint will be broken. If after fully exploiting this process, it still cannot produce enough products to meet market demand, other way to increase capacity should be found out.
5) **Repeat for other constraint (if any):** If the constraint is broken, step 1 is repeated. When that happens, there will be another constraint, somewhere else in the system that is limiting progress to the goal. It is very important not to let inertia become a constraint.

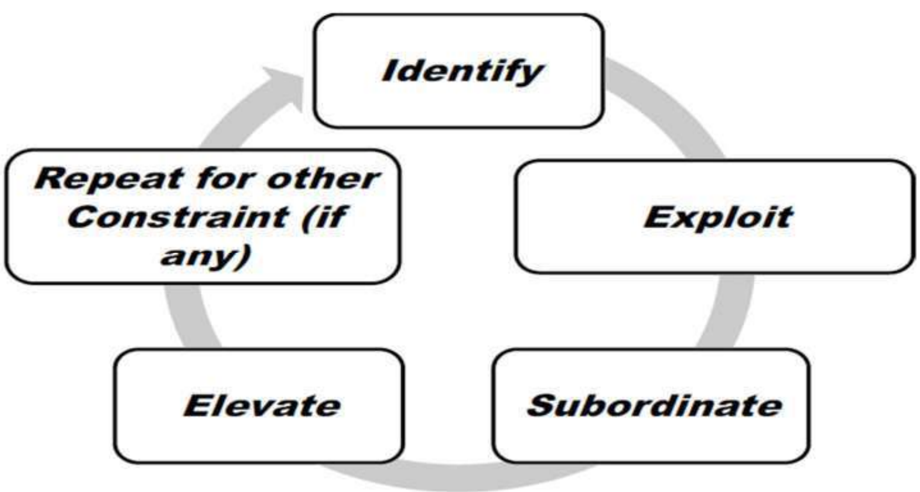


Figure: TOC Process

TOC Thinking Processes:

In order to continually identify the constraints, TOC provides a theoretical framework and the tools to do so. There are five thinking process tools that allows executives to identify what to change in the organization, what to change it into and how to implement the change. The five tools are as follows:

1. ***Current Reality Tree:*** Captures the experience and intuition of the involved individuals. It identifies the root causes and the core problem of an organization.
2. ***Evaporating cloud:*** Identifies a solution to the core problem previously identified. It helps uncover the conflict that brought about the core problem in the first place.
3. ***Future Reality Tree:*** Identifies what is missing from our solution. It allows us to evaluate and improve our solution before it being implementing.
4. ***Prerequisite Tree:*** Identifies all the intermediate steps that are needed to reach the chosen solution.
5. ***Transition Tree:*** Identifies those actions needed, given the current environment, to achieve the intermediate objectives that were identified earlier with the prerequisite tree.

Operation Planning and control based on Theory of Constraints:

Within manufacturing operations and operations management, the solution seeks to pull materials through the system, rather than push them into the system. The primary methodology used is drum-buffer-rope (DBR) and a variation called simplified drum-buffer-rope (S-DBR).

Drum-buffer-rope is a manufacturing execution methodology based on the fact the output of a system can only be the same as the output at the constraint of the system. Any attempt to produce more than what the constraint can process just leads to excess inventory piling up. The method is named for its three components. The *drum* is the rate at which the physical constraint of the plant can work: the work center or machine or operation that limits the ability of the entire system to produce more. The rest of the plant follows the beat of the drum. Schedule at the drum decides what the system should produce, in what sequence to produce and how much to produce. They make sure the drum has work and that anything the drum has processed does not get wasted.

The *buffer* protects the drum, so that it always has work flowing to it. Buffers in DBR provide the additional lead time beyond the required set up and process times, for materials in the product flow. Since these buffers have time as their unit of measure, rather than quantity of material, this makes the priority system operate strictly based on the time an order is expected to be at the drum. Each work order will have a remaining buffer status that can be calculated. Based on this buffer status, work orders can be color coded into Red, Yellow and Green. The red orders have the highest priority and must be worked on first, since they have penetrated most into their buffers followed by yellow and green. As time evolves, this buffer status might change and the color assigned to the particular work order change with it.

Traditional DBR usually calls for buffers at several points in the system: the constraint, synchronization points and at shipping. S-DBR has a buffer at shipping and manages the flow of work across the drum through a load planning mechanism.

The *rope* is the work release mechanism for the plant. Orders are released to the shop floor at one "buffer time" before they are due to be processed by the constraint. In other words, if the buffer is 5 days, the order is released 5 days before it is due at the constraint. Putting work into the system earlier than this buffer time is likely to generate too-high work-in-process and slow down the entire system.

Measures of performance:

For a manufacturing organization, with the goal being to make money now as well as in the future, TOC defines three operational measurements that measure whether operations are working towards the goal. They are:

a) **Throughput:** The rate at which a system generates money through sales. This is considered to be the same as contribution margin (selling price-cost of raw material). Labour costs are considered to be part of operating expense rather than throughput. Sales are only recognized when the money is available to the firm. That is production for inventory is not part of throughput.
b) **Inventory:** All the money the system invests in things it intends to (or could) sell. This is the total system investment, which includes not only conventional inventory, but also buildings, land, vehicles, plant and equipment. It does not include the value of labour added to WIP inventory.
c) **Operating Expense:** All the money the system spends in turning Inventory into Throughput. This includes all of the money constantly poured into a system to keep it operating, such as direct labour, heat, light, scrap materials, depreciation, etc.

These measures are financial in nature, i.e. they can be translated to measure such as Net Profit and Return on Investment; are easy to apply at any level of company; and Ensures that local decisions are aligned with the profit goal of the firm. The following four measurements are used to identify results for the overall organization:

Net Profit = Throughput – Operating Expense

Return on Investment (ROI) = (Throughput – Operating Expense)/Inventory

Productivity = Throughput/Operating Expense

Turnover = Throughput/Inventory

Constraints in Manufacturing System:

In manufacturing, TOC uses constraint management to ensure continuous improvement through synchronized manufacturing (see Figure). The basic steps involved in synchronization are to: 1) identify the constraint resources; 2) establish key buffer locations to protect throughput; 3) schedule the constraint resource; 4) release materials at gateway operations to maximize production at the constraint resource; and

5) use forward scheduling of work centers that follow the constraint resource to ensure high levels of duedate performance. This approach, which links all manufacturing resources to the constraint resource, is known as Drum-Buffer-Rope synchronization.

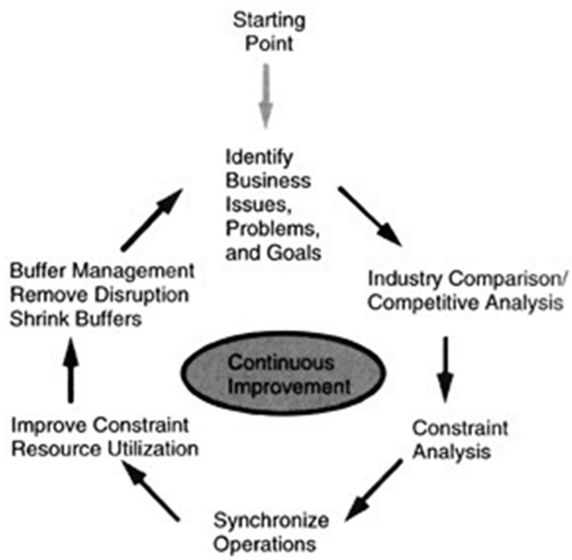


Figure: Synchronized Manufacturing

Drum-Buffer-Rope Synchronization:

Synchronize to the Drum – Subordination

After the drum has been scheduled, material release and shipping are connected to it, using the buffer offset. Material is released at the same rate as the drum can consume it. Orders are shipped at the rate of drum production.

DBR Scheduling Algorithm

- The process of scheduling the factory first focuses on the primary objective of the facility, to ship to committed delivery date. Thus we first find the due date of the order, and add a shipping buffer to create an "ideal" finish date with confidence.
- From this planned finish date, the order is backward scheduled to identify an "ideal" time to work on the drum resource, a "latest due by" (LBD) date.
- All orders are scheduled to fit on the drum using two passes; first, by assigning all batches an ideal placement on the drum schedule.
- When the batch does not fit, i.e., there is another occupying its space, the batch is scheduled earlier in time so the order due date is not violated. This may result in some jobs starting before today, and not all jobs may be ready to start at the drum resource.
- The drum is then forward scheduled to resolve these conflicts, and potentially late jobs are identified (the red batch).

- After the drum is schedule, the operations after the drum are scheduled forward in time from the drum completion date.
- Then, the jobs feeding the drum are backward scheduled from the start of the resource buffer.

Plant Types in TOC:

There are four primary types of plants in the TOC lexicon. Draw the flow of material from the bottom of a page to the top, and you get the four types. They specify the general flow of materials through a system, and they provide some hints about where to look for typical problems. The four types can be combined in many ways in larger facilities.

- ***I-plant:*** Material flows in a sequence, such as in an assembly line. The primary work is done in a straight sequence of events (one-to-one). The constraint is the slowest operation.
- ***A-plant:*** The general flow of material is many-to-one, such as in a plant where many sub-assemblies converge for a final assembly. The primary problem in A-plants is in synchronizing the converging lines so that each supplies the final assembly point at the right time.
- ***V-plant:*** The general flow of material is one-to-many, such as a plant that takes one raw material and can make many final products. Classic examples are meat rendering plants or a steel manufacturer. The primary problem in V-plants is "robbing" where one operation (A) immediately after a diverging point "steals" materials meant for the other operation (B). Once the material has been processed by A, it cannot come back and be run through B without significant rework.
- ***T-plant:*** The general flow is that of an I-plant (or has multiple lines), which then splits into many assemblies (many-to-many). Most manufactured parts are used in multiple assemblies and nearly all assemblies use multiple parts. Customized devices, such as computers, are good examples. T-plants suffer from both synchronization problems of A-plants (parts aren't all available for an assembly) and the robbing problems of V-plants (one assembly steals parts that could have been used in another).

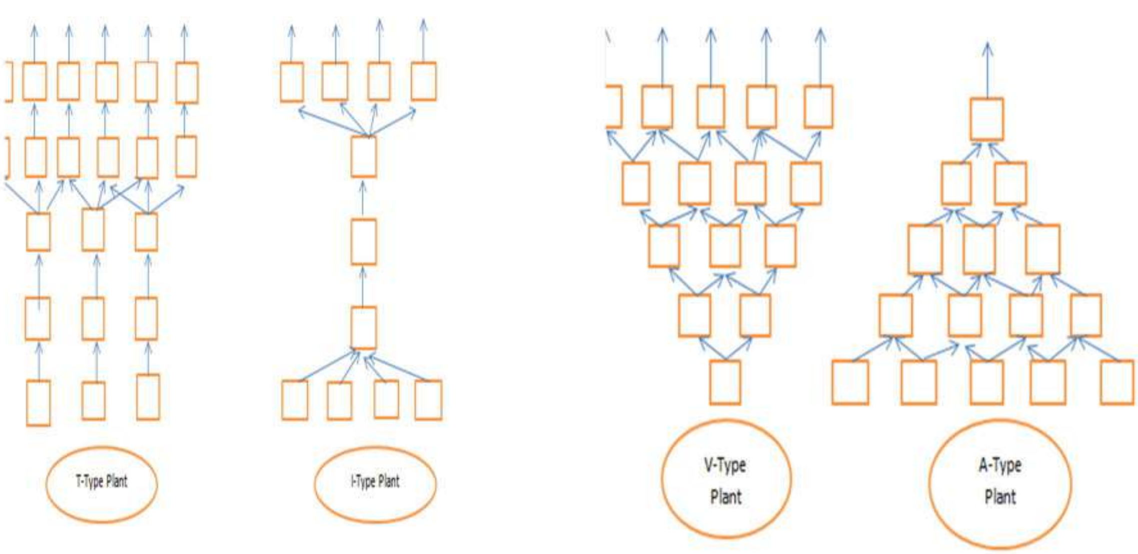


Figure: Plant Types in TOC

Drum-Buffer-Rope (DBR) Methodology:

Buffers:

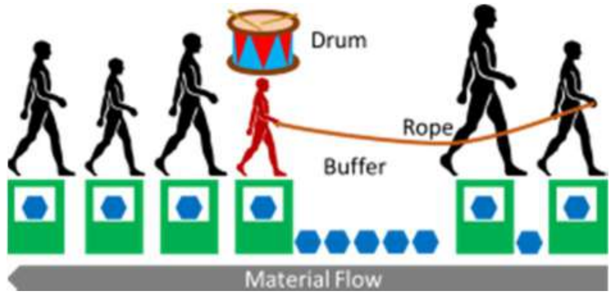
Buffers are used throughout the theory of constraints. They often result as part of the exploit and subordinate steps of the five focusing steps. Buffers are placed before the governing constraint, thus ensuring that the constraint is never starved. Buffers are also placed behind the constraint to prevent downstream failure to block the constraint's output. Buffers used in this way protect the constraint from variations in the rest of the system and should allow for normal variation of processing time and the occasional upset (Murphy) before and behind the constraint. Buffers can be a bank of physical objects before a work center, waiting to be processed by that work center. Buffers ultimately buy you time, as in the time before work reaches the constraint and are often verbalized as time buffers. There should always be enough (but not excessive) work in the time queue before the constraint and adequate offloading space behind the constraint. Buffers are not the small queue of work that sits before every work center in a Kanban system although it is similar if you regard the assembly line as the governing constraint. A prerequisite in the theory is that with one constraint in the system, all other parts of the system must have sufficient capacity to keep up with the work at the constraint and to catch up if time was lost. In a balanced line, as espoused by Kanban, when one work center goes down for a period longer than the buffer allows, then the entire system must wait until that work center is restored. In a TOC system, the only situation where work is in danger, is if the constraint is unable to process (either due to malfunction, sickness or a "hole" in the buffer – if something goes wrong that the time buffer cannot protect). Buffer management therefore represents a crucial attribute of the theory of constraints. There are many ways to do it, but the most often used is a visual system of designating the buffer in three colors: green (okay), yellow (caution) and red (action required). Creating this kind of visibility enables the system as a whole to align and thus subordinate to the need of the constraint in a holistic manner. This can also be done daily in a central operations room that is accessible to everybody.

Drum-Buffer-Rope (DBR) Methodology:

Drum Buffer Rope (DBR) is a planning and scheduling solution derived from the Theory of Constraints (ToC).

The fundamental assumption of DBR is that within any plant there is one or a limited number of scarce resources which control the overall output of that plant. Synchronizing to this resource creates a drumbeat or pace of production. The plan for this resource is called “drum”. Other resources, (non-constraints) then match their pace to this resource.

The plan for production is centered on this resource and during execution, the management and shop floor behaviors are focused on exploiting it, maximizing its production and protecting it against disruption through the use of “time buffers”. This behavior synchronizes and subordinates all other resources and decisions to the activity of the drum through a mechanism that is akin to a “rope”.

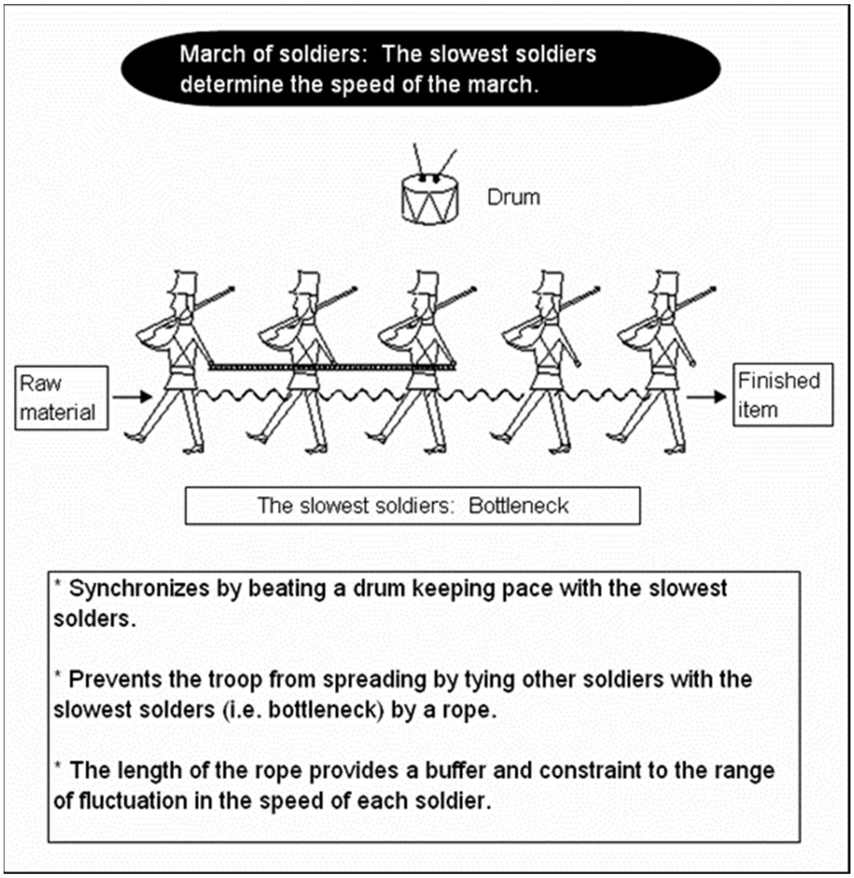


DBR concerns itself with:

1. Creating a realistic plan or schedule that makes the "best: use of capacity to maximize profitability (Throughput, Inventory, and Operating Expenses).
2. Creating the behaviors to effectively execute the plan.
3. Providing feedback to identify opportunities to improve the system's performance over time.

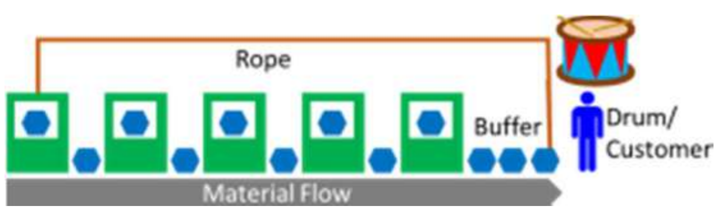
As in an example of boy scouts hiking, those who are bottlenecks are positioned at the beginning and a rope is used for subordinating (synchronizing) the speed of followers with that of the bottleneck persons. This enables preventing the march (work-in-process inventory) from expanding. In other words, to eliminate work-in-process inventory is to reduce costs. Also, in preventing the front ones of the bottleneck group who determine the marching speed of the entire team from slowing down, a rope plays an important role as a buffer to absorb the changes in the marching speed of the front ones of the bottleneck group. A drum plays a role of conveying the information about the speed of the slowest bottleneck persons to everyone in the group and cheering up the bottleneck persons to raise their speed up.

When the rope is stretched out to the limit, it is necessary to impose a constraint on those who tied to the rope so that they will not be able to raise the speed any further. In some cases, work needs to suspend when the buffer reaches the limit. Similarly, the team may sometimes need to stop. If the drum is beaten at the speed of the first person of the team, an interval with the following persons will get wider and wider. In that case, the inventory level will increase and throughput will decrease. If the drum is beaten at the speed of the last person of the team, i.e. the team marches at the speed of the inventory, the inventory level will decrease and throughput will increase as the speed of demand increases. The pull-type system means to beat a drum at the speed of the last person, which corresponds to as demand-driven pull type supply chain management.



Simplified Drum Buffer Rope (S-DBR):

Simplified Drum-Buffer-Rope is very similar to Drum-Buffer-Rope. The key to simplifying the approach is the assumption that the market or the customer is the largest bottleneck. I.e. in average your system always has enough capacity to satisfy demand. The rope then spans the entire length of the system.

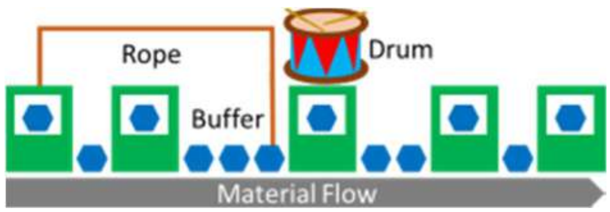


Benefits of the SDBR:

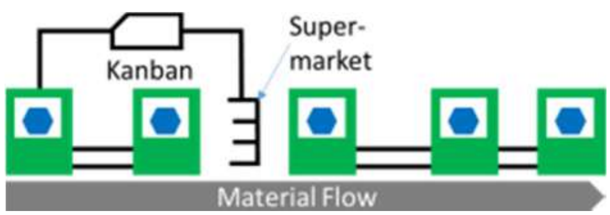
1) Simpler to implement.
2) Having just one buffer makes the priority list clear at all times.
3) Maintaining much more flexibility to meet the changing requirements of the clients.
4) Signals clearly that the major constraint is the market demand, thus even the CCR (capacity resource constraint) should subordinate to it.

Drum Buffer Rope for Manufacturing Systems:

In manufacturing, the drum is still the bottleneck. The buffer is the material upstream of the bottleneck and has to make sure that the drum is never starved. The rope is a signal or information from the buffer to the beginning of the line. If the drum processes parts, the buffer moves forward. The rope is a signal when material is taken out, and gives an information to replenish another part at the beginning of the line as shown in the Illustration below.



Signal when material is taken out … information to replenish … I have heard something very similar before … Kanban! Yes, Drum-Buffer-Rope is similar to Kanban with the supermarket before the bottleneck. Whenever a part is taken out of the **buffer/supermarket**, a signal is sent via the **rope/kanban** to the beginning of the **line/Kanban loop** to replenish material. A Drum-Buffer-Rope system as shown above is very similar to a Kanban loop as shown below.



However, there are some differences which I would like to go into some detail below. But before that first for completeness sake another variant of Drum-Buffer-Rope, the Simplified Drum-Buffer-Rope:

Benefits of TOC

The theory of constraints does away with much of cost accounting. It is clear that application of cost accounting principles (primarily the allocation of costs in order to make decisions at the local level) leads to poor management decisions at the department as well as in upper levels of the organization. In fact, TOC virtually eliminates the use of Economic Order Quantities (EOQ), production lot sizes, deriving product costs, setting prices, determining productivity measures and the use of performance incentives.

Most individuals will readily see the use for the theory of constraints in the improvement of production scheduling or in improving manufacturing. This is simply incorrect. Although it is true that the Theory of Constraints provides us with simple examples in the manufacturing environments, TOC is truly applicable to any process in organization. This includes universities, hospitals, service provider of all varieties, government and of course manufacturing.

Application areas of TOC

The theory of constraints has been used at three different levels:

a) ***Production Management***– TOC was initially applied here to solve problems of bottlenecks, scheduling and inventory reduction.
b) ***Throughput Analysis***– Application of TOC has caused a shift from cost-based decision making to decision making based on continuous improvement of processes in which system throughput, system constraints and statically determined protective capacities at critical points are key elements.
c) ***Theory of Constraints Logical Processes***– This third level is the general application of TOC reasoning to attack a variety of process problems within organizations. TOC logic is applied to identify what factors are limiting an organization for achieving its goal, developing a solution to the problem and getting the individuals in the process to invent the requisite changes from themselves.

Flexible Manufacturing System (FMS):Definition

A **Flexible Manufacturing System** (**FMS**) is a manufacturing system in which there is some amount of flexibility that allows the system to react in case of changes, whether predicted or unpredicted. This flexibility is generally considered to fall into two categories, which both contain numerous subcategories.

The first category, *routing flexibility*, covers the system's ability to be changed to produce new product types, and ability to change the order of operations executed on a part. The second category is called *machine flexibility*, which consists of the ability to use multiple machines to perform the same operation on a part, as well as the system's ability to absorb large-scale changes, such as in volume, capacity, or capability. Flexibility in manufacturing means the ability to deal with slightly or greatly mixed parts, to allow variation in parts assembly and variations in process sequence, change the production volume and change the design of certain product being manufactured.

Flexibility and Its Types:

Flexibility is an attribute that allows a mixed model manufacturing system to cope up with a certain level of variations in part or product style, without having any interruption in production due to changeovers between models. Flexibility measures the ability to adapt “to a wide range of possible environment”. To be flexible, a manufacturing system must possess the following capabilities:

1) Identification of the different production units to perform the correct operation
2) Quick changeover of operating instructions to the computer controlled production machines
3) Quick changeover of physical setups of fixtures, tools and other working units

The different types of flexibility that are exhibited by manufacturing systems are given below:

1. **Machine Flexibility**. It is the capability to adapt a given machine in the system to a wide range of production operations and part styles. The greater the range of operations and part styles the greater will be the machine flexibility. The various factors on which machine flexibility depends are:

i. Setup or changeover time
ii. Ease with which part-programs can be downloaded to machines
iii. Tool storage capacity of machines
iv. Skill and versatility of workers in the systems

2. **Production Flexibility**. It is the range of part styles that can be produced on the systems. The range of part styles that can be produced by a manufacturing system at moderate cost and time is determined by the process envelope. It depends on following factors:

i. Machine flexibility of individual stations
ii. Range of machine flexibilities of all stations in the system

3. **Mix Flexibility**. It is defined as the ability to change the product mix while maintaining the same total production quantity that is, producing the same parts only in different proportions. It is also known as process flexibility. Mix flexibility provides protection against market variability by accommodating changes in product mix due to the use of shared resources. However, high mix variations may result in requirements for a greater number of tools, fixtures, and other resources. Mixed flexibility depends on factors such as:

i. Similarity of parts in the mix
ii. Machine flexibility
iii. Relative work content times of parts produced

4. **Product Flexibility**. It refers to ability to change over to a new set of products economically and quickly in response to the changing market requirements. The change over time includes the time for designing, planning, tooling, and fixturing of new products introduced in the manufacturing line-up. It depends upon following factors:

i. Relatedness of new part design with the existing part family
ii. Off-line part program preparation
iii. Machine flexibility

5. **Routing Flexibility**. It can define as capacity to produce parts on alternative workstation in case of equipment breakdowns, tool failure, and other interruptions at any particular station. It helps in increasing throughput, in the presence of external changes such as product mix, engineering changes, or new product introductions. Following are the factors which decides routing flexibility:

i. Similarity of parts in the mix
ii. Similarity of workstations

iii. Common tooling

6. **Volume Flexibility**. It is the ability of the system to vary the production volumes of different products to accommodate changes in demand while remaining profitable. It can also be termed as capacity flexibility. Factors affecting the volume flexibility are:

i. Level of manual labor performing production
ii. Amount invested in capital equipment.

7. **Expansion Flexibility**. It is defined as the ease with which the system can be expanded to foster total production volume. Expansion flexibility depends on following factors:

i. Cost incurred in adding new workstations and trained workers
ii. Easiness in expansion of layout
iii. Type of part handling system used

Since flexibility is inversely proportional to the sensitivity to change, a measure of flexibility must quantify the term "penalty of change (POC)", which is defined as follows:

POC = penalty x probability

Here, penalty is equal to the amount upto which the system is penalized for changes made against the system constraints, with the given probability. Lower the value of POC obtained, higher will be the flexibility of the system.

Types of Flexible Manufacturing System (FMS):

Flexible manufacturing systems can be divided into various types depending upon their features. They all are discussed below:

1. Depending upon kinds of operation:

Flexible manufacturing system can be distinguished depending upon the kinds of operation they perform:

I. **Processing operation.** Such operation transforms a work material from one state to another moving towards the final desired part or product. It adds value by changing the geometry, properties or appearance of the starting materials.

II. **Assembly operation.** It involves joining of two or more component to create a new entity which is called an assembly/subassembly. Permanent joining processes include welding, brazing, soldering , adhesive bonding, rivets, press fitting, and expansion fits.

2. Depending upon number of machines:

The following are typical categories of FMS according to the number of machines in the system:

I. single machine cell (SMC). It consist of a fully automated machine capable of unattended operations for a time period longer than one machine cycle. It is capable of processing different part styles, responding to changes in production schedule, and accepting new part introductions. In this case processing is sequential not simultaneous.

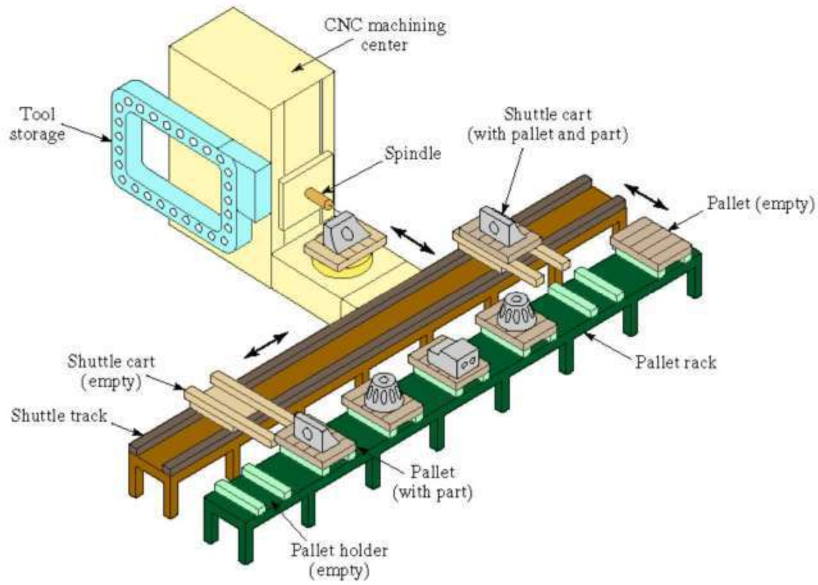


Figure : Single machine cell with one CNC machining centre and parts storage unit

II. Flexible manufacturing cell (FMC). It consists of two or three processing workstation and a part handling system. The part handling system is connected to a load/unload station. It is capable of simultaneous production of different parts.

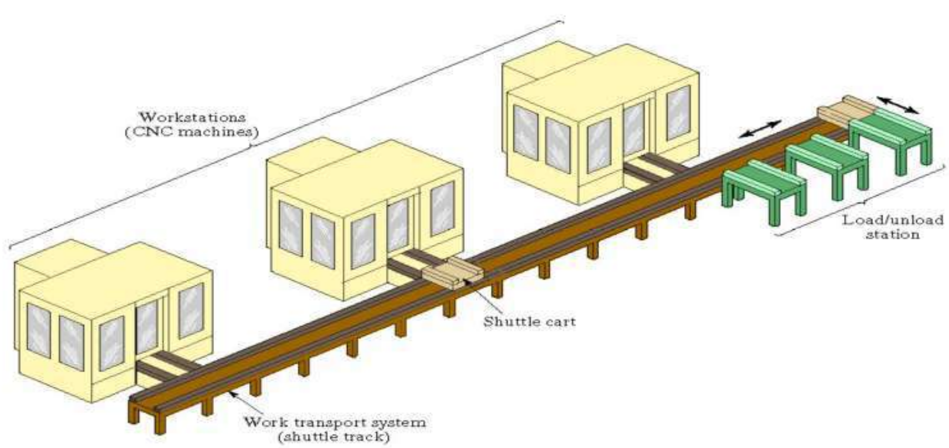


Figure: Flexible manufacturing cell with three identical processing stations, a load/unload station, and parts handling system

III. A Flexible Manufacturing System (FMS). It has four or more processing work stations (typically CNC machining centers or turning centers) connected mechanically by a common part handling system and automatically by a distributed computer system. It also includes non-processing work stations that support production but do not directly participate in it. e.g. part / pallet washing stations, co-ordinate measuring machines. These features significantly differentiate it from Flexible manufacturing cell (FMC).

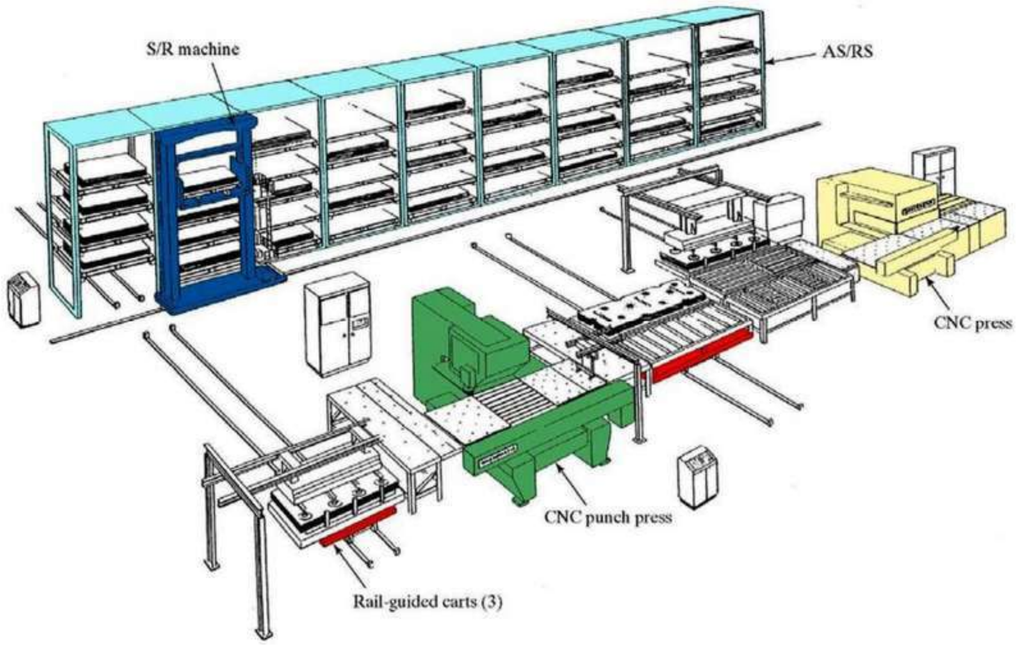


Figure: Felxible Maufacturing System for Automated Sheet Metal Processing

3. Depending upon level of flexibility:

Another classification of FMS is made according to the level of flexibility associated with the system. Two categories are distinguished here:

I. **Dedicated FMS.** It is designed to produce a particular variety of part styles. The product design is considered fixed. So, the system can be designed with a certain amount of process specialization to make the operation more efficient.

II. Random order FMS. It is able to handle the substantial variations in part configurations. To accommodate these variations, a random order FMS must be more flexible than the dedicated FMS. A random order FMS is capable of processing parts that have a higher degree of complexity. Thus, to deal with these kinds of complexity, sophisticated computer control system is used for this FMS type.

Components of Flexible Manufacturing System (FMS):

A flexible manufacturing system consists of two subsystems:

1) Physical subsystem
2) Control subsystem

Physical subsystem includes the following elements:

1. **Workstations**. It consists of NC machines, machine-tools, inspection equipments, loading and unloading operation, and machining area.

2. Storage-retrieval systems. It acts as a buffer during WIP (work-in-processes) and holds devices such as carousels used to store parts temporarily between work stations or operations.

3. Material handling systems. It consists of power vehicles, conveyers, automated guided vehicles (AGVs), and other systems to carry parts between workstations.

Control subsystem comprises of following elements:

1. Control hardware. It consists of mini and micro computers, programmable logic controllers, communication networks, switching devices and others peripheral devices such as printers and mass storage memory equipment to enhance the working capability of the FMS systems.

2. Control software. It is a set of files and programs that are used to control the physical subsystems. The efficiency of FMS totally depends upon the compatibility of control hardware and control software.

Basic features of the physical components of an FMS are discussed below:

1. Numerical control machine tools

Machine tools are considered to be the major building blocks of an FMS as they determine the degree of flexibility and capabilities of the FMS. Some of the features of machine tools are described below;

i. The majority of FMSs use horizontal and vertical spindle machines. However, machining centers with vertical spindle machines have lesser flexibility than horizontal machining centers.
ii. Machining centers have numerical control on movements made in all directions e.g. spindle movement in x, y, and z directions, rotation of tables, tilting of table etc to ensure the high flexibility.
iii. The machining centers are able to perform a wide variety of operations e.g. turning, drilling, contouring etc. They consist of the pallet exchangers interfacing with material handling devices that carry the pallets within and between machining centers as well as automated storage and retrieval systems.

2. Work holding and tooling considerations

It includes pallets/fixtures, tool changers, tool identification systems, coolant, and chip removal systems. It has the following features:

i. Before machining is started on the parts, they are mounted on fixtures. So, fixtures must be designed in a way, to minimize part-handling time. Modular fixturing has come up as an attractive method to fixture a variety of parts quickly.

ii. The use of automated storage and retrieval system (AS/RS) and material handling systems such as AGVs, lead to high usage of fixtures.

iii. All the machining centers are well equipped with tool storage systems called tool magazines. Duplication of the most often used tools in the tool magazines is allowed to ensure the least non-operational time. Moreover, employment of quick tool changers, tool regrinders and provision of spares also help for the same.

3. Material-Handling Equipments:

The material-handling equipment used in flexible manufacturing systems include robots, conveyers, automated guided vehicle systems, monorails and other rail guided vehicles, and other specially designed vehicles. There important features are:

i. They are integrated with the machine centers and the storage and retrieval systems.

ii. For prismatic part material handling systems are accompanied with modular pallet fixtures. For rotational parts industrial robots are used to load/unload the turning machine and to move parts between stations.

iii. The handling system must be capable of being controlled directly by the computer system to direct it the various work station, load/unload stations and storage area.

4. Inspection equipment

It includes coordinate measuring machines (CMMs) used for offline inspection and programmed to measure dimensions, concentricity, perpendicularity, and flatness of surfaces. The distinguishing feature of this equipment is that it is well integrated with the machining centers.

5. Other components

It includes a central coolant and efficient chip separation system. Their features are:

i. The system must be capable of recovering the coolant.

ii. The combination of parts, fixtures, and pallets must be cleaned properly to remove dirt and chips before operation and inspection.

Conceptual Model of FMS:

FMS Layouts:

Progressive Layout: Best for producing a variety of parts

Closed Loop Layout:

- Parts can skip stations for flexibility
- Used for large part sizes
- Best for long process times

Ladder Layout:

- Parts can be sent to any machine in any sequence
- Parts not limited to particular part families

Open Field Layout:

- Most complex FMS layout
- Includes several support stations

Advantages of FMS:

1) Reduced manufacturing cost
2) Lower cost per unit produced,
3) Greater labor productivity,
4) Greater machine efficiency,
5) Improved quality,
6) Increased system reliability,
7) Reduced parts inventories,
8) Adaptability to CAD/CAM operations.
9) Shorter lead times
10) Improved efficiency
11) Increase production rate

Disadvantages of FMS:

1) Initial set-up cost is high,
2) Substantial pre-planning
3) Requirement of skilled labor
4) Complicated system
5) Maintenance is complicated

Application of FMS:

i. Metal cutting machining
ii. Metal forming
iii. Assembly
iv. Joining- welding (arc , spot), glueing
v. Surface treatment

vi. Inspection
vii. Testing

Machine Loading and Scheduling:

Machine Loading:

Machine loading problem of a flexible manufacturing system is known for its complexity, which encompasses various types of flexibility aspects pertaining to part selection and operation assignments along with constraints ranging from simple algebraic to potentially complex and conditional one. Decision pertaining to machine loading problems has been considered as tactical level planning decision that acts as a tie between strategic and operating level decision in manufacturing. It receives the input from preceding decision levels, such as part mixes selection, resource grouping, aggregate planning, etc and transfer it to the succeeding decision levels of resources scheduling and dynamic operation planning and control.

Objective of Machine Loading Problems:

1. Balancing the machine processing time;
2. Minimizing the number of movement;
3. Balancing the workload per machine for a system of groups of pooled machines of equal sizes;
4. Unbalancing the workload per machine for a system of groups of pooled machines of unequal sizes;
5. Filling the tool magazines as densely as possible;
6. Maximizing the sum of operations priorities.

Scheduling:

i. Scheduling is the process of arranging, controlling and optimizing work and workloads in a production process or manufacturing process.
ii. Scheduling is used to allocate plant and machinery resources, plan human resources, plan production processes and purchase materials.
iii. In manufacturing, the purpose of scheduling is to minimize the production time and costs, by telling a production facility when to make, with which staff, and on which equipment.
iv. Production scheduling aims to maximize the efficiency of the operation and reduce costs.
v. Scheduling may be defined as the assignment of work to the facility with the specification of time, and the sequence in which the work is to be done.
vi. Scheduling deals with orders and machines. It determines which order will be taken up on which machine in which department at what time and by which operator.
vii. Scheduling is the process of arranging, controlling and optimizing work and workloads in a production process. Companies use backward and forward scheduling to allocate plant and machinery resources, plan human resources, plan production processes and purchase materials.

Key concepts in Scheduling:

A key character of scheduling is the productivity, the relation between quantity of inputs and quantity of output. Key concepts here are:

1) ***Inputs:*** Inputs are plant, labor, materials, tooling, energy and a clean environment.
2) ***Outputs:*** Outputs are the products produced in factories either for other factories or for the end buyer. The extent to which any one product is produced within any one factory is governed by transaction cost.
3) ***Output within the factory:*** The output of any one work area within the factory is an input to the next work area in that factory according to the manufacturing process. For example, the output of cutting is an input to the bending room.
4) ***Output for the next factory:*** By way of example, the output of a paper mill is an input to a print factory. The output of a petrochemicals plant is an input to an asphalt plant, a cosmetics factory and a plastics factory.
5) ***Output for the end buyer:*** Factory output goes to the consumer via a service business such as a retailer or an asphalt paving company.
6) ***Resource allocation:*** Resource allocation is assigning inputs to produce output. The aim is to maximize output with given inputs or to minimize quantity of inputs to produce required output.

Objectives of Scheduling:

- **i.** Scheduling aims to achieve the required rate of o/p with a minimum delay and disruption in processing.
- **ii.** To provide adequate quarters of goods necessary to maintain finished product at levels predetermined to meet the delivery commitment.
- **iii.** The aim of loading and scheduling is to have maximum utilization of men, machines and materials by maintaining a free flow of materials along the production line.
- **iv.** To prevent unbalanced allocation of time among production departments.
- **v.** To keep the production cost minimum.

Elements of Scheduling:

Scheduling determines the timings and order of the operations to optimize the use of resources to meet production requirements. The following are the elements of scheduling.

a. Job arrival patterns
b. Number and variety of machines /operations
c. Ratio of workers to machines/operations
d. Flow pattern of jobs
e. Priority rules for allocating work

Principles of Scheduling:

In view of the direct equivalence between the workflow and cash flow, scheduling should be done with utmost care .The following are the major principles of scheduling.

- **i.** Effectiveness should be measured by speed of workflow
- **ii.** Scheduling jobs as a string with process step back
- **iii.** A job started should not be interrupted
- **iv.** Speed of flow is most efficiently achieved by focusing on bottlenecks
- **v.** Reschedule every day
- **vi.** Obtain feedback on each job at each work center every day
- **vii.** Match the work center input information to that the worker can actually do
- **viii.** When seeking improvement in output, look for incompatibility between engineering design and process execution
- **ix.** Always work to attain certainty of standards and routings.

Factors Affecting Scheduling:

(A) External Factors

- Customers demand
- Customers delivery dates
- Stock of goods already lying with the dealers & retailers.

(B) Internal Factors

- Stock of finished good with firm
- Time interval to manufacture each component, subassembly and then assembly.
- Availability of equipments & machinery their capacity & specification.
- Availability of materials
- Availability of manpower

Scheduling Priority Rules:

A sample set of priority rules are presented below. There are six kinds of rules for operation selecting from the given allowed set.

1) *Short Processing Time (SPT):* Process the operation with minimum processing time.
2) *Most Work Remaining (MWR):* Process the operation among the tasks with the maximum total processing time.
3) *Random Selecting Rule:* Select an operation from the giving allowed set with a random way.
4) *Long Processing Time (LPT):* Process the operation with maximal processing time.
5) *Most Operation Remaining (MOR):*Process the operation among the tasks with most remaining operation.
6) *Earliest due date Rule(EDD)Rule:* The earliest due date rule minimizes the maximum job lateness,

or job tardiness, but unfortunately it tends to need more tasks and increased the mean tardiness.

Scheduling Procedure:

Scheduling is a process of adding start and finish time information to the job order dictated in the sequencing process. Sequencing process in turn, is defined as getting the order in which jobs are to be run on a machine. The sequence thus obtained determines the schedule, since we assume each job is started on the machine as soon as the job has finished all predecessor operations and the machine has completed all earlier jobs in the sequences. This is referred to as semi-active schedule and acts as an optimal policy for minimizing the completion time, flow time, lateness, tardiness, and other measures of performance. Scheduling problems are often denoted by N/ M/ F/ P, where N is the number of jobs to be scheduled, M is the number of machines, F refers to the job flow pattern, and P is performance measures that are to be appropriately minimized or maximized. The solution of scheduling problems are generally presented in the form of Gannt-chart which is a chart plotted between different work centers and total processing time on that work center.

Gantt Chart:

i. A Gantt chart is a type of bar chart that illustrates a project schedule, named after its inventor, Henry Gantt (1861–1919), who designed such a chart around the years 1910–1915.

ii. A Gantt chart is a type of bar chart that illustrates a project schedule. This chart lists the tasks to be performed on the vertical axis, and time intervals on the horizontal axis. The width of the horizontal bars in the graph shows the duration of each activity.

iii. Gantt charts illustrate the start and finish dates of the terminal elements and summary elements of a project. Terminal elements and summary elements constitute the work breakdown structure of the project. Modern Gantt charts also show the dependency (i.e., precedence network) relationships between activities.

iv. Gantt charts are graphical representations of task-based projects. The tasks in a Gantt chart are both listed in a tabular format and displayed graphically as task bars, reflecting their duration. By linking related tasks, Visio can automatically adjust the timeline when tasks are delayed or completed before schedule.

v. Hence, Gantt charts are the ideal tool to use if you are responsible for scheduling a project and tracking the duration of each of the tasks in the project to ensure the project is completed on time.

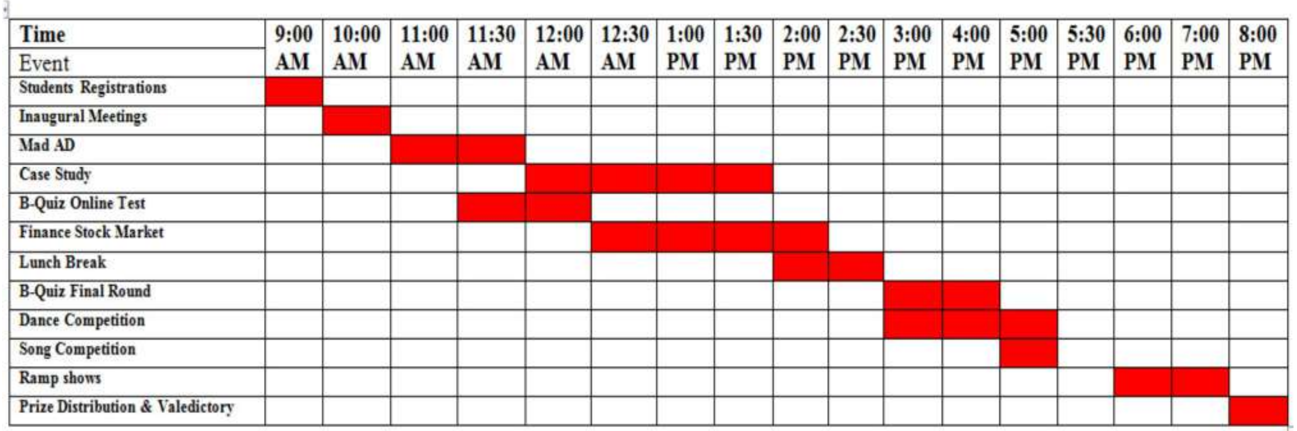
vi. Gantt charts are usually created initially using an early start time approach, where each task is scheduled to start immediately when its prerequisites are complete. This method maximizes the float time available for all tasks.

The Gantt chart is a popular method commonly used in scheduling technique. An example of Gantt chart is shown below.

Time Table for B-Fest Meet-2019@ BIITM

Event	Timing	Venue
Students Registration	9:00 AM to 10:00 AM	**Near Entry Gate**
Inaugural Meeting	10:00 AM to 10:45 AM	**KDM Hall (Second Floor)**
Mad AD	(10:00 AM to 11:30 PM)	**Lawn & Open Stage**
B-Quiz Online Test	(11:00 AM to 12:00 PM)	**Computer Lab-1 (Ground Floor)**
Case Study	(11:30 AM to 1:30 PM)	**1st Floor (SSD & Seminar Hall)**
Finance Stock Market	(12:00 PM to 2:00 PM)	**Computer Lab-1 (Ground Floor)**
Lunch Break 1:30 PM to 2:30 PM		
B-Quiz Final Round	2:30 PM to 4:00 PM	**KDM Hall (Second Floor)**
Dance Competition	2:30 PM to 5:00 PM	**Open Stage**
Song Competition	4:00 PM to 5:00 PM	**KDM Hall (Second Floor)**
Ramp shows	5:30 PM to 7:00 PM	**Open Stage**
Prize Distribution & Valedictory	7:00 PM to 8:00 PM	**Open Stage**

Gantt Chart for B-Fest Meet-2019 @ BIITM



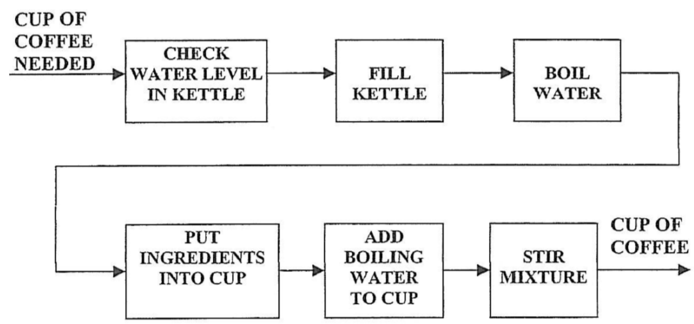
MANAGEMENT OF MANUFACTURING SYSTEM(MMS)

4TH SEMESTER MBA (OPERATION SPECIALIZATION)

SHORT QUESTIONS (2 MARKS)

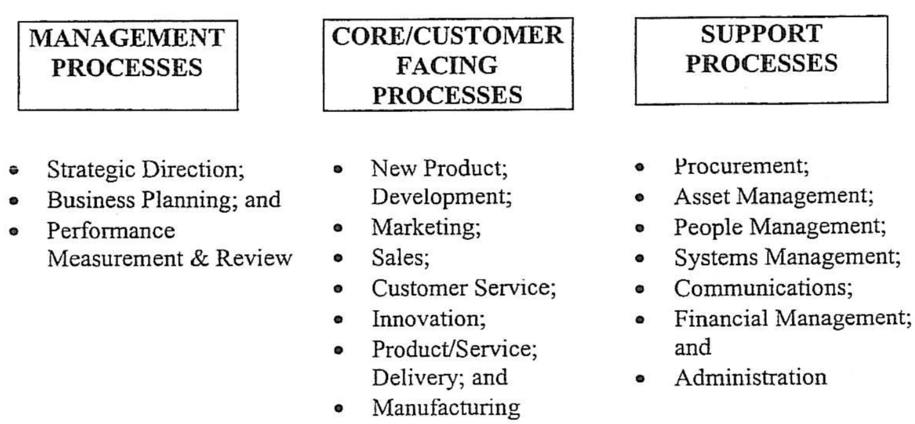
Q.1 What do you mean by Process Flow charts?

A Process Flow charts is used to show the sequence of activities within the process. A flowchart covering the activities which is shown in below (Example Process Flow Chart of making a cup of Coffee)



Q.2 What is Process Atlas?

All organization has key processes that make up its process Atlas. While organization vary widely in size and culture they nearly all have similar top level processes, even though the individual activities in each process may differ from one organization to another. These can be split into groups as in the following example;



Q. 3 Write-down the Objective of Manufacturing Process Planning.

i. The chief of process planning is to augment and modernize the business methods of a company. Process planning is planned to renovate design specification into manufacturing instructions and to make products within the function and quality specification at the least possible costs.

ii. This will result in reduced costs, due to fewer staff required to complete the same process, higher competence, by eradicating process steps such as loops and bottlenecks, greater precision, by including checkpoints and success measures to make sure process steps are completed precisely, better understanding by all employees to fulfill their department objectives.

Q.4 what do you mean by Computer Aided Process Planning?

Computer-aided process planning (CAPP) is the use of computer technology to aid in the process planning of a part or product, in manufacturing. CAPP is the link between CAD and CAM in that it provides for the planning of the process to be used in producing a designed part.

Q. 5 Define Manufacturing Concept Planning.

The solution of manufacturing process planning is a complicated and combined problem therefore it is necessary to divide the tasks into hierarchical levels. The first level of this hierarchy is called preliminary process planning or Manufacturing concept planning, which is the conceptual level of the planning process. The most important tasks of preliminary process planning are;

i. The preparation of process planning of blank manufacturing, the part manufacturing and the assembly;
ii. Correction of the design documents in the view point of manufacturability and assimilability;
iii. Selection of manufacturing system;
iv. Analysis of the manufacturing tasks and estimation of manufacturing cost and time data.

Q. 6 Define the Computer integrated manufacturing.

Computer-integrated manufacturing (CIM) is the use of computer techniques to integrate manufacturing activities. These activities encompass all functions necessary to translate customer needs into a final product. CIM starts with the development of a product concept that may exist in the marketing organization; includes product design and specification, usually the responsibility of an engineering organization; and extends through production into delivery and after-sales activities that reside in a field service or sales organization. Integration of these activities requires that accurate information be available when needed and in the format required by the person or group requesting the data.

Q. 7 What is Computer Aided manufacturing?

a) Computer-aided manufacturing (CAM) commonly refers to the use of numerical control (NC) computer software applications to create detailed instructions (G-code) that drive computer numerical control (CNC) machine tools for manufacturing parts. Manufacturers in a variety of industries depend on the capabilities of CAM to produce high-quality parts.
b) A broader definition of CAM can include the use of computer applications to define a manufacturing plan for tooling design, computer-aided design (CAD) model preparation, NC programming, coordinate measuring machine (CMM) inspection programming, machine tool simulation, or post-processing. The plan is then executed in a production environment, such as direct numerical control (DNC), tool management, CNC machining.

Q.8 What do you mean by Assembly Lines?

i. An arrangement of machines, equipment, and workers in which work passes from operation to operation in direct line until the product is assembled.
ii. A process for turning out a finished product in a mechanically efficient manner.
iii. A manufacturing tool first made popular by Henry Ford in his manufacturing of automobiles. The principle of an assembly line is that each worker is assigned one very specific task, which he or she simply repeats, and then the process moves to the next worker who does his or her task, until the task is completed and the product is made. It is a way to mass produce goods quickly and efficiently. All workers do not have to be human; robotic workers can make up an assembly line as well.

Q. 9 What are the Factors that affecting Facility Layout?

1) Plant location and building
2) Nature of product
3) Types of industry
4) Plant environment
5) Spatial requirement
6) Repair and Maintenance
7) Balance
8) Management policy
9) Human needs
10) Types of machinery and equipment.

Q. 10 Define Cellular Manufacturing Systems (Group Technology)?

i. In Group Technology or Cellular manufacturing layout, machines are grouped into cell and the cell function somewhat like a product layout within a larger shop or process layout.
ii. A grouping of equipment for performing a sequence of operations on family of similar components or products has become all the important.
iii. Group technology (GT) is the analysis and comparisons of items to group them into families with similar characteristics.
iv. GT can be used to develop a hybrid between pure process layout and pure flow line (product) layout.

Q.11 Define Computerized Relative Allocation of Facilities Technique (CRAFT).

CRAFT algorithm was originally developed by Armour and Buffa. It is an improvement algorithm. It starts with an initial layout and improves the layout by interchanging the departments pairwise so that the transport cost is minimized. The algorithm continues until not further interchanges are possible to reduce the transportation cost. The result given by CRAFT is not optimum in terms of minimum cost of transportation.

Q. 12 What do you mean by Scale Models?

It is an improvement over the template method. In this tool, instead of templates, use of three dimensional scale models is made. These models may be of wood or metal and when used on a layout, series of additional information about the height and of the projected parts of the machines are obtained. This is similar to a child's doll house. This technique is useful for complex layout, requiring initially huge investment

Q. 13 Define Production Flow Analysis (PFA).

i. Developed by Burbridge in 1971, is a method for identifying part families and associated machine groupings that uses the information contained on production route sheets rather on part drawings.
ii. Work parts with identical or similar routings are classified into part families.
iii. PFA neither uses a classification and coding system nor part drawings to identify families.
iv. It uses the information such as part number, operation sequence, lot size, etc., contained on the route sheet.
v. This method is based on the route sheet information and sometimes referred as the route sheet inspection method.
vi. Steps Involved in PFA:The following four steps are followed to carryout PFA:
    (i) Data collection
    (ii) Sortation of process routings
    (iii) Preparation of PFA chart
    (iv) Cluster analysis.

Q.14 What do you mean by Seven waste?

The seven wastes originated in Japan, where waste is known as **"Muda." "The seven wastes"** is a tool to further categorize **"Muda"** and was originally developed by Toyota's Chief Engineer Taiichi Ohno as the core of the Toyota Production System, also known as Lean Manufacturing. To eliminate waste, it is important to understand exactly what waste is and where it exists. While products significantly differ between factories, the typical wastes found in manufacturing environments are quite similar. For each waste, there is a strategy to reduce or eliminate its effect on a company, thereby improving overall performance and quality.

Q.15 Define Kanban System.

Kanban was developed by Taiichi Ohno, an industrial engineer at Toyota, as a system to improve and maintain a high level of production.The Kanban Method is as an approach to incremental, evolutionary process and systems change for organizations. It uses a work-in-progress limited pull system as the core mechanism to expose system operation (or process) problems and stimulate collaboration to continuously improve the system.

Q. 16 Define the term Constant Work–in–Process (CONWIP).

CONWIP, standing for *Constant Work In Progress* and developed by Mark Spearman and Wallace Hopp in 1990. it, tries to mix push and pull approaches: it schedules tasks for each station – with a push approach – while production is triggered by inventory events, which is a pull rule. Thus, CONWIP is card-based, as kanban systems, but cards do not trigger the production of a single component in the closest upward workstation; conversely, cards are used to start the whole production line, from beginning downwards.

Q. 17 What is POLCA?

The POLCA (Paired-Cell Overlapping Loops of Cards with Authorization), which stands at the base of the Quick Response Manufacturing (QRM) approach, proposed in 19981. QRM aims to minimize lead times rather than addressing waste reduction, as TPS does. A series of tools, such as manufacturing critical-path time, cellular organization, batch optimization and high level MRP, are used to minimize stock levels: the lesser is the lead time, the lesser is the on-hand inventory. Likewise CONWIP, POLCA handles WIP (Work in Process) proliferation originating from multiple products, since it does not require each station to have a base stock of each component.

Q 18 What do you mean by Theory of constraint?

a) The theory of constraints (TOC) is a relatively recent development in the practical aspect of making organizational decisions in situations where constraints exist. Dr. Eliyahu M. Goldratt first described the theory in his novel, The Goal, which was published in the year 1992.
b) TOC is a systems approach based on the assumption that every organization has at least one factor that inhibits the organization’s ability to meet its objectives. The normal objective for a business is to maximize profit.
c) The TOC emphasizes the maximization of profit by assuring that the factor that limits production is used most efficiently. Manufacturing philosophy based on TOC focuses on change at three levels (the 3Ms): the Mindset of the organization, the Measures that drive the organization and the Methods employed within the organization.

Q. 19 Define the term Drum buffer rope?

Drum Buffer Rope (DBR) is a planning and scheduling solution derived from the Theory of Constraints (ToC). The fundamental assumption of DBR is that within any plant there is one or a limited number of scarce resources which control the overall output of that plant. Synchronizing to this resource creates a drumbeat or pace of production. The plan for this resource is called “drum”. Other resources, (non-constraints) then match their pace to this resource.

Q. 20 What is heijunka box ?

A heijunka box is a sort of enhanced kanban board: it still acts as a visual scheduling tool to obtain production leveling at the workstations. However, differently from the traditional board, it manages to keep evidence of materials distinctions. Usually, it is represented as a grid-shaped wall schedule. Analogously to the simpler board, each row represents a time interval (usually, 30-60 minutes), but multiple columns are present, each one associated to a different material.

Q. 21 What is the role of theory of constraint in manufacturing?

In manufacturing, TOC uses constraint management to ensure continuous improvement through synchronized manufacturing . The basic steps involved in synchronization are to:

a. identify the constraint resources;
b. establish key buffer locations to protect throughput;
c. schedule the constraint resource;
d. release materials at gateway operations to maximize production at the constraint resource; and
e. use forward scheduling of work centers that follow the constraint resource to ensure high levels of due date performance. This approach, which links all manufacturing resources to the constraint resource, is known as Drum-Buffer-Rope synchronization

Q 22 What do you mean by Flexible Manufacturing System (FMS)?

i. A Flexible Manufacturing System (FMS) is a manufacturing system in which there is some amount of flexibility that allows the system to react in case of changes, whether predicted or unpredicted.
ii. Flexibility in manufacturing means the ability to deal with slightly or greatly mixed parts, to allow variation in parts assembly and variations in process sequence, change the production volume and change the design of certain product being manufactured.

Q.23 Define Machine Loading problem.

Machine loading problem of a flexible manufacturing system is known for its complexity, which encompasses various types of flexibility aspects pertaining to part selection and operation assignments along with constraints ranging from simple algebraic to potentially complex and conditional one. Decision pertaining to machine loading problems has been considered as tactical level planning decision that acts as a tie between strategic and operating level decision in manufacturing.

Q 24 What is the Objectives of Scheduling?

i. Scheduling aims to achieve the required rate of o/p with a minimum delay and disruption in processing.
ii. To provide adequate quarters of goods necessary to maintain finished product at levels predetermined to meet the delivery commitment.
iii. The aim of loading and scheduling is to have maximum utilization of men, machines and materials by maintaining a free flow of materials along the production line.
iv. To prevent unbalanced allocation of time among production departments.
v. To keep the production cost minimum.

Q. 25 Define Gantt Chart.

i. A Gantt chart is a type of bar chart that illustrates a project schedule, named after its inventor, Henry Gantt (1861–1919), who designed such a chart around the years 1910–1915.
ii. A Gantt chart is a type of bar chart that illustrates a project schedule. This chart lists the tasks to be performed on the vertical axis, and time intervals on the horizontal axis. The width of the horizontal bars in the graph shows the duration of each activity.
iii. Gantt charts are graphical representations of task-based projects. The tasks in a Gantt chart are both listed in a tabular format and displayed graphically as task bars, reflecting their duration. By linking related tasks, Visio can automatically adjust the timeline when tasks are delayed or completed before schedule.

MANAGEMENT OF MANUFACTURING SYSTEM (MMS)

4TH SEMESTER MBA (OPERATION SPECIALIZATION)

Multiple Choice Questions with Answers

MODULE-1

Q.1. ____________is used to show the sequence of activities within the process.

a) Process Flow Sequence
b) Process Flow Charts
c) Process Atlas
d) Process Atlas Chart

Q.2. Which process include casting , forging, stamping, embossing, spinning etc. for change the shape of the work piece without necessarily removing or adding material?

a) Forming processes
b) Machining processes
c) Welding processes
d) Assembly processes

Q. 3. It is a process of shaping a metal by pressing it against a form or mandrel while it is rotating on a high speed lathe is called;

a) Spinning
b) Machining
c) Welding
d) Soldering

Q.4________________is the use of computer technology to aid in the process planning of a part or product, in manufacturing. Which play the link between CAD and CAM in that it provides for the planning of the process to be used in producing a designed part?

a) Manufacturing Process Planning
b) Manufacturing Concept Planning
c) Computer-aided process planning (CAPP)
d) None of the Above

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Q. 5 the solution of manufacturing process planning is a complicated and combined problem therefore it is necessary to divide the tasks into hierarchical levels. The first level of this hierarchy is called_________.

a) Manufacturing Process Planning
b) Manufacturing Concept Planning
c) Computer-Aided Process Planning
d) Assembly Lines

Q. 6.______________________is the use of computer techniques to integrate manufacturing activities. These activities encompass all functions necessary to translate customer needs into a final product.

a) Computer-Aided Design (CAD)
b) Computer-Aided Manufacturing (CAM)
c) Computer-Integrated Manufacturing (CIM)
d) Computer-Aided Process Planning (CAPP)

Q. 7.______________________refers to the use of numerical control (NC) computer software applications to create detailed instructions (G-code) that drive computer numerical control (CNC) machine tools for manufacturing parts.

a) Computer-Aided Design (CAD)
b) Computer-Aided Manufacturing (CAM)
c) Computer-Integrated Manufacturing (CIM)
d) Computer-Aided Process Planning (CAPP)

Q.8. An arrangement of machines, equipment, and workers in which work passes from operation to operation in direct line until the product is assembled is called__________.

a) Assembly Lines
b) Lines of Manufacturing
c) Material Flow
d) None of the Above

Q. 9. which of the following is not the Factors that affecting Facility Layout?

a) Plant location and building
b) Cost
c) Nature of product
d) Types of industry

Q.10. ________________is the analysis and comparisons of items to group them into families with similar characteristics.

a) Product Layout
b) Group Technology (GT)
c) Manufacturing Line
d) None of the Above

Q.11. CRAFT algorithm Stand for

a) Coordination Relative Allocation of Full Technique (CRAFT).
b) Computerized Relative Allocation of Facilities Technique (CRAFT).
c) Computerized Relation Allocation of Facilities Tools (CRAFT).
d) Computerized Relative Application of Facilities Technics (CRAFT).

Q. 12. These models may be of wood or metal and when used on a layout, series of additional information about the height and of the projected parts of the machines are obtained is called_________.

a) Basic Model
b) Design Model
c) Scale Models
d) Template Model

Q. 13. It is used in environments where product demand is unstable, and the workstations in the facility can be easily rearranged. This type of environment often exists in firms that do mostly subcontracting work is known as_________________.

a) Virtual Manufacturing Cells
b) Dynamic Manufacturing Cells
c) Hybrid Manufacturing Cells
d) Cellular Manufacturing Cells

Q. 14._____________system is machine intensive; most of the work content of operations is done by machines and not the workers.

a) Rapid manufacturing cells
b) Classical manufacturing cells
c) Virtual manufacturing cells
d) Dynamic manufacturing cells

Q. 15. Product layout is best suited for:

a) mass production
b) job production
c) batch production
d) all of the above

Q. 16. Line organization is also known as:

a) functional organization
b) military organization
c) staff and functional organization
d) none of the above

Q. 17. A factory produces goods to stock stores and showrooms. By predicting the market for their goods, the manufacturer will plan production activity in advance.

a) Make-To-Order (MTO)
b) Make-To-Stock (MTS)
c) Make-To-Assemble (MTA)
d) Make-To-Assemble (MTA)

Q. 18. Which is not includes in Process Mapping in Work Environment?

a) Supplies of products and materials are available
b) Product are researched and designed
c) Product are marketed and sold
d) Products are manufactured
e) None of the above

Q. 19. Which is not involved in Production Flow Analysis (PFA)?

a) Cost of Data collection
b) Sortation of process routings
c) Preparation of PFA chart
d) Cluster analysis.

Q. 20. These cards give complete specification of each machine to be installed such as output capacity, foundations, space needed, method of operation, maintenance and handling devices of machines etc. is known as__________.

a) Kanban card
b) Machine Data Cards
c) Hijuka card
d) Poka Yoke card

Q. 21. The following type of Layout caters to ‘intermittent flow’ type of production.

a) Process layout
b) Product layout
c) Combined layout
d) All of the above

Q. 22. Cellular manufacturing is also known as

a) Manufacturing Technology
b) Production Technology
c) Group Technology
d) None of the above

Q. 23. Cellular manufacturing is an approach whereby production can be done in

a) Small batches
b) Medium batches
c) Large batches
d) Any of the above

Q. 24. The following is (are) the advantage(s) of Cellular manufacturing.

a) Very little in-process inventory
b) More job satisfaction
c) Reduced flow times
d) All of the above

Q. 25. In a simple and visual method of Cell design, the priorities in classifying may be in the order

a) Rotational or non rotational – Material – Size – Shape
b) Material – Rotational or non rotational – Size – Shape
c) Size – Rotational or non rotational – Material – Shape
d) Shape – Rotational or non rotational – Material – Size

Q. 26 The following cell formation technique is based on Component shape and design?

a) Production flow analysis
b) Component flow analysis
c) Composite component
d) Simulation

Q. 27. In cell formation using production flow analysis, following process will be left out of analysis

a) Grinding
b) Milling
c) Drilling
d) Gear cutting

Q. 28. Which of the following technique of grouping does not consider the design and shape aspect?

a) A simple and visual method of cell design
b) Family formation by classification and codification
c) Cell formation using Production Flow Analysis
d) All of the above

Q. 29. The following is basically a material flow simplification technique.

a) A simple and visual method of cell design
b) Family formation by classification and codification
c) Cell formation using Production Flow Analysis
d) All of the above

Q. 30. The following is (are) the benefit(s) of Cellular Manufacturing.

a) Job satisfaction
b) Job enlargement
c) Both (a) and (b)
d) Job enrichment

Q. 31. Which of the following statement is not true for breakeven analysis?

(a) Fixed cost does not vary with total production
(b) Total cost varies with the total production
(c) Variable cost is dependent on total production
(d) Breakeven point is the point where fixed cost line and variable cost line intersect with each other on a volume cost graph.

Q. 32. The symbol of rectangle shape represents the process of ……….. in the process analysis.

(a) Transportation
(b) Operation
(c) Inspection
(d) Delay

Q. 33. Which of the following is not a type of flow process chart?

(a) Material
(b) Method
(c) Machine
(d) Man

Q. 34. Which of the following is not the definition of Quality?

(a) conformance of specification
(b) Fitness for use
(c) Spare part maintenance
(d) Customer delight

Q. 35. In a …………. Layout all machines or process of the same type are grouped together.

(a) Fixed position
(b) Factory

(c) Process
(d) Product

Q. 36. Mass production is characterized by

(a) Low volume high variety
(b) High volume low variety
(c) High volume high variety
(d) Low volume low variety

Q. 37. …………… process chart is a graphic representation of the sequence of all the operations and inspections involved in a process or procedure.

(a) Operation
(b) Outline
(c) Travel
(d) Flow process

Q. 38. The most popular type of organisation used for Civil Engineering Constructions is

a) Line organization
b) Line and staff organization
c) Functional organization
d) Effective organization

Q. 39. Which one of the following chart gives simultaneously information about the progress of work and machine loading?

a) Process chart
b) Machine load chart
c) Man-machine chart
d) Gantt chart

Q. 40. Merit Rating is the method of determining worth of

a) A job
b) An individual employee
c) A particular division in workshop
d) Machine

Q. 41. Bin card is used in

a) Administrative wing
b) Workshop
c) Foundry shop
d) Stores

Q. 42. The production scheduling is simpler and high volume of output and high labour efficiency are achieved in the case of

(A) Product layout
(B) Process layout
(C) Fixed position layout
(D) A combination of line and process layout

Q. 43. The disadvantage of product layout is

a) High initial investment for the specialized facilities
b) Skilled labour to operate machines
c) Production time is longer, requiring more goods in inventory
d) High cost of inspection

Q. 44. Material handling in automobile industry is done by

a) Overhead crane
b) Trolley
c) Belt conveyor
d) All of the above
e) None of the above.

Q. 45. String diagram is used when

a) Team of workers is working at a place
b) Material handling is to be done
c) Idle time is to be reduced
d) All of the above
e) None of the above.

Q. 46. The standard time for a job is

a) Total work content
b) Basie time + relaxation time
c) Total work content + basic time
d) Total work content + delay contingency allowance
e) Total work content + relaxation time.

Q. 47. Gantt chart provides information about the

a) Material handling
b) Proper utilization of manpower
c) Production schedule
d) Efficient working of machine
e) All of the above.

Q. 48. Process layout is employed for

a) Batch production
b) Continuous type of product
c) Effective utilization of machines
d) All of the above
e) None of the above.

Q. 49. For a product layout the material handling equipment must

a) Have full flexibility
b) Employ conveyor belts, trucks, tractors etc.
c) Be a general purpose type
d) Be designed as special purpose for a particular application
e) Arranging shops according to specialization of duties.

Q. 50. The process layout is best suited where

(a) Specialization exists
(b) Machines are arranged according to sequence of operation
(c) Few number of non-standardized units is to be produced
(d) Mass production is envisaged
(e) Bought out items are more.

MODULE-2

Q.1. In Just-In-Time system

a) There is no delay
b) Conveyance times are balanced
c) Both (A) and (B)
d) There is unequal production at different places

Q.2. Just-In-Time is

a) Single unit production
b) Big lot size production
c) Both (A) and (B)
d) None of the above

Q.3. Just-In-Time aimed at

a) Zero inventories
b) Reduced manpower
c) Over production
d) All of the above

Q.4. Just-In-Time (JIT) combines the benefits of

a) Job order production and Line production
b) Batch production and Line production
c) Job order production and Batch production
d) None of the above

Q.5. JIT does not believe in

a) Quality
b) Over production
c) Human relations
d) All of the above

Q.6. The seven wastes originated in Japan, where waste is known as____________________.

a) Mode
b) Muda
c) Muri
d) Mune

Q.7. Lean manufacturing is a (n):

a) Fad.
b) Method for reducing labor.
c) Way to improve customer value
d) Efficiency improvement technique

Q.8. Cycle-time-efficiency is:

a) Improved by increasing utilization.
b) The machine cycle divided by number of pieces produced.
c) Increased by larger lot size.
d) Value-added time over elapsed time

Q.9. What is the objective of the Toyota Production System and Lean Manufacturing?

a) To reduce cost
b) To improve profit
c) To eliminate everything that does not add value for the customer
d) To optimize capital investment

Q.10. It was developed by Taiichi Ohno, and It uses a work-in-progress limited pull system as the core mechanism to expose system operation (or process) problems and stimulate collaboration to continuously improve the system is called________________.

a) Kanban system
b) Work–in–process
c) Cellular manufacturing system
d) None of the above

Q.11. In the context of Just in Time systems, which statement about 'kanbans' is false?

a) When no output has been requested, operatives are encouraged to do physical exercises to keep fit
b) Workstations are not allowed to produce anything without a kanban
c) Physical form of a kanban may be a container in which the requested parts are delivered
d) Kanban is a 'pull' system

Q.12. In the context of a JIT manufacturing system, which of the following is not true?

a) Production line problems are put to one side and dealt with later
b) Minimizing inventory improves cash flow
c) Additional advantage of low stock levels is that quality problems cannot be hidden
d) Production line stoppages very quickly attract management attention

Q.13. How does Kanban prevent work over capacity?

a) By using Work In Progress (WIP) Limit.
b) By setting a robust Kanban workflow.
c) By having daily meetings about work in progress.
d) By defining explicit policies

Q.14. Which one of the following is a reason to use the Kanban "pull" method in production planning?

a) It supports the use of long term accurate planning by producing maximum throughput.
b) It optimizes the use of resources.
c) It makes the requirement of long term accurate planning almost obsolete.
d) Both b & c

Q.15. What does a policy in a Kanban board signify?

a) The pre-requisites a card should fulfill to be placed in a specific column/status.
b) The contents of a Kanban card.
c) The required Kanban workflow a board should have.
d) All above choices.

Q.16. _______________system is very similar to a Kanban system, except that, it is not associated with a certain part type, but only with a certain quantity (also at least one).

a) Constant Work In Progress (CONWIP)
b) Constant Work In Process (CONWIP)
c) Constant Work In Production (CONWIP)
d) Continuous Work In Progress (CONWIP)

Q.17. Which one of the following is correct about a Kanban Card?

a) Kanban card is a way of signaling which parts are available.
b) Kanban card is attached to each item to provide details of the transaction history.
c) Kanban card is destroyed once a bin is empty.
d) Kanban card is a message that signals the actual status of an item, parts, or requirement in knowledge work such as software engineering.

Q.18. When is a signal to replenish stock sent in a Kanban's Two-Bin System?

a) When an item is taken from the first bin.
b) When both the first and second bins are empty.
c) When the first bin is empty.
d) When the first bin is halfway done.

Q.19. Why must Kanban teams enable quick, constant, and secure feedback loops?

a) To fulfill client needs and make them happy.
b) To remove flaws and inefficiencies from the Kanban workflow.
c) To learn from impediments and avoid running into them in the future.
d) All above choices.

Q.20. What is POLCA?

a) POLCA (Process-Cell Overlapping Loops of Cards with Authenticate)
b) POLCA (Production-Cell Overlapping Loops of Cards with Authorization)
c) POLCA (Paired-Cell Overlapping Limits of Cards with Authenticate)
d) POLCA (Paired-Cell Overlapping Loops of Cards with Authorization)

Q.21. ____________ acts as a visual scheduling tool to obtain production leveling at the workstations. However, differently from the traditional board, it manages to keep evidence of materials distinctions.

a) Tool Box
b) Heijunka Box
c) Visual Scheduling Tool Box
d) Material Box

Q.22. ______________is an evolution of JIT, which embeds the CONWIP idea of mixing push/requirement and pull/replenishment production management systems.

a) Just in Time
b) Just in Sequence
c) Zero Defects
d) Single Kanban Card

Q.23. In the theory of constraints, a constraint is

a) A policy that limits throughput.
b) An activity or operation that limits throughput.
c) A scarce resource that limits throughput.
d) a. and b.
e) a., b. and c.

Q.24. According to Goldratt, floating bottlenecks are created by

a) Dependent events.
b) Statistical fluctuations.
c) Attempts to balance the plant.
d) The combination of a., b. and c.
e) None of the above

Q.25. According to Goldratt, floating bottlenecks are caused by the combination of

a) An unbalanced plant, constraints and dependent events.
b) A balanced plant, constraints and statistical fluctuations.
c) An unbalanced plant and statistical fluctuations.
d) A balanced plant, dependent events and statistical fluctuations.
e) An unbalanced plant, dependent events and statistical fluctuations.

Q.26. In the theory of constraints, increasing inventory (as defined in TOC) without affecting throughput or operating expense, would automatically

a) Increase net income.
b) Decrease net income.
c) Increase return on investment.
d) Decrease return on investment.
e) Produce none of the above.

Q.27. In the theory of constraints, balancing the flow of work requires

a) Breaking the constraint.
b) Working at the pace set by the constraint.
c) Balancing the plant.
d) a. and b.
e) a., b. and c.

Q. 28. Drum Buffer rope (DBR) method is used in which scheduling problem?

a) Job shop
b) Flow shop
c) Single machine
d) Young machine

Q. 29. If the operation is cash constrained it may use:

a) Shortest operation time first
b) First in first out
c) Due date
d) Last in first out
e) Longest operation time first

Q. 30. The 'drum, buffer, rope', concept comes from:

a) The theory of behaviour and financial theory
b) Disconfirmation theory
c) The theory of constraints and optimized production technology
d) Inventory theory and automated engineering concepts

Q. 31. A ‘bottleneck’ resource needs to process those materials that result into

a) Throughput
b) Finished goods
c) Products
d) Products with least wastes

Q. 32. Non-bottleneck resources may have excess capacity, that can be used as

a) Preventive maintenance
b) Set up
c) Address of special problems
d) All of the above

Q. 33. Available time at a resource can be used as

a) Waiting time
b) Processing time
c) Set up time
d) All of the above

Q. 34. As per TOC concept, any business organization has two generic goals. The first one is to make money, now and in future. What is the second goal?

a) To maintain good industrial relations
b) To minimize production cost
c) To maintain smooth flow of materials with in the production or service systems
d) To establish a process of continuous improvement

Q. 35. Activation of resources results in its utilization under TOC logic. Activitation may result in:

a) Generation of throughput
b) Generation of non-throughput
c) Both (a) and (b)
d) None of (a) and (b)

Q. 36. The main purpose of TOC is

a) To balance the flow of work
b) To balance the flow of materials
c) To balance the capacity of resources
d) All of the above

Q. 37. Let bottleneck resource is A and non-bottleneck resource is B. if the relationship between A and B is shown as A → B, it means

a) A is activated as per requirements of B
b) B is activated as per requirements of A
c) Both be activated as per requirements of another resource
d) None of the above

Q. 38. A process batch at a non-bottleneck resource should be

a) Less than that of another bottleneck resource
b) Less than that of bottleneck resource it feeds
c) As small as possible equal to transfer batch

d) All of the above

Q. 39. The classical EOQ model is not applicable under TOC concept. The reason is:

a) It does not consider throughput
b) It does not consider constraints
c) It is accost-based approach
d) All of the above

Q. 40. A CCR must be considered for product flow planning if

a) It is a bottleneck resource
b) It is a non-bottleneck resource
c) It is either a bottleneck or a non-bottleneck resource
d) None of the above

Q. 41. In D-B-R scheduling we need to consider 'schedule release points' as a critical issue. These release points are classified into

a) 3 categories
b) 4 categories
c) 5 categories
d) 6 categories

Q. 42. A T-plant is a T-shaped process flow that has

a) A single raw material and a large number of end items
b) A single raw material and specific end item with a set of models
c) A single material and a single end item
d) Limited number of components and a large number of end items

Q. 43. In the context of Lean Production, which one of the following statements is untrue?

a) The focus of Lean Production is on the product, not the customer
b) Value for customers is created by reducing or eliminating waste
c) Lean Production relies heavily on the Just-In-Time management model
d) The main idea of lean production is to create value for customers

Q. 44. Which term (or terms) below is (are) associated with floating bottlenecks?

a) dependent events
b) independent events.
c) statistical fluctuations
d) b and c.
e) a and c.

Q. 45. The cost of operation such as wages, salaries, deprecation, utilities and rents are summned together to calculate;

a) Throughput cost
b) Investments
c) Operating cost
d) Marginal cost

Q. 46. In the context of Just In Time systems, which statement about 'kanbans' is false?

a) When no output has been requested, operatives are encouraged to do physical exercises to keep fit
b) Physical form of a kanban may be a container in which the requested parts are delivered
c) Kanban is a 'pull' system
d) Workstations are not allowed to produce anything without a kanban

Q. 47. Which one of the following items is not part of the fundamental JIT concept?

a) Right place
b) Right customer
c) Right time
d) Right components
e) Right quantities

Q. 48. In order to cope with changes in demand, organisations often use some of the following techniques as a buffer around a stable core of capacity:

a) Decision trees / forward loading / inventory
b) Master production scheduling / inventory / order backlog
c) Inventory / forward loading / short-term capacity adjustments
d) Inventory / short-term capacity adjustments / Taguchi techniques
e) Short-term capacity adjustments / decision trees / forward loading

Q. 49. Kanban Bins includes;

a) Indicator Bins
b) Colored Bins
c) Bins with Labels
d) Highly Visible Bins
e) All of the Above

Q. 50. POK stands for

a) Product ordering Kanban
b) Process Ordering Kanban
c) Production Ordering Kanban
d) Plan Ordering Kanban

MODULE-3

Q. 1. In the theory of constraints, throughput refers to;

a) Sales dollars less direct materials and direct labor costs.
b) Sales dollars less direct materials costs.
c) Sales dollars less variable cost of goods sold.
d) The cost of total production output.
e) The cost of good production output.

Q. 2. An objective in the theory of constraints is to;

a) Balance the capacity of each operation in the plant so that all operations will produce at the same pace.
b) Balance the flow of work by allowing the most binding constraint to set the pace for the plant.
c) Balance the capacity of each operation by recognizing the variability within the system.
d) Balance the flow of work by allowing each operation to produce at it's own pace.
e) None of the above

Q. 3. The drum in a theory of constraints system

a) Enforces the pace.
b) Authorizes production.
c) Protects the pace.
d) Sets the pace.
e) None of these.

Q. 4. In a theory of constraints system, throughput is

a) The money flowing into the system.
b) The money flowing out of the system.
c) The money in the system.
d) Sales dollars.
e) None of these.

Q. 5. A bottleneck is where

a) The demand on a resource is greater than the capacity of the resource.
b) The demand on a resource is equal to the capacity of the resource.
c) Buffer inventory should be avoided.
d) a. and b.
e) a., b. and c

Q. 6. Throughput is

a) Money generated by the company.
b) Sales.
c) Sales - operating expense.
d) Sales - inventory.
e) None of these.

Q.7. In the theory of constraints, inventory is defined as

a) Direct materials included in the products sold.
b) Total assets.
c) Assets - liabilities.
d) Sales - throughput.
e) None of the above.

Q.8. According to the theory of constraints, which of the following is not, or are not global measurements?

a) traditional product costs.
b) activity based product costs.
c) throughput.
d) a and b.
e) b and c.

Q.9. A technique associated with the theory of constraints is referred to as the drum-buffer-rope method. In this method the most binding constraint is the

a) buffer
b) rope
c) drum
d) a and c
e) none of these.

Q.10. __________________means the ability to deal with slightly or greatly mixed parts, to allow variation in parts assembly and variations in process sequence, change the production volume and change the design of certain product being manufactured.

a) Parts assembly System
b) Design assembly System
c) Flexible Manufacturing System (FMS)
d) None of the Above

Q.11. ROI in the theory of constraints is

a) Money generated by the company divided by inventory.
b) (Sales - COGS)/Inventory.
c) (Sales - operating expense)/Inventory.
d) (Throughput - operating expense)/Inventory.
e) None of these.

Q.12. Flexible manufacturing systems (FMS) are reported to have a number of benefits. Which is NOT a reported benefit of FMS?

a) Lead time and throughput time reduction
b) Increased utilization
c) More flexible than the manufacturing systems they replace
d) Increased quality

Q. 13. Which materials-processing technology gives the advantage of precision, accuracy and optimum use of cutting tools, which maximise their life and higher labour productivity?

a) Flexible manufacturing systems (FMS)
b) Computer-integrated manufacturing (CIM)
c) NC (and CNC) machine tools
d) Industrial robots

Q.14. What do Flexible Manufacturing systems (FMS) do?

a) Completely manufactures a range of components without significant human intervention during the processing
b) Moves and manipulates products, parts or tolls
c) Moves materials between operations
d) Co-ordinates the whole process of manufacturing and manufactures a part, component or product

Q.15. Process technologies differ in their flexibility capabilities and economics and will therefore be appropriate for different parts of the volume-variety matrix. Flexible manufacturing systems are usually:

a) Mid variety, mid volume
b) High variety, low volume
c) Mid variety, high volume
d) Low variety, mid volume

Q. 16. Which of the following are examples of materials processing technologies?

a) None of the below
b) Electronic point of sale technology
c) Bar code scanners
d) Airline check-in

Q.17. _____________achieve the required rate of output with a minimum delay and disruption in processing and have maximum utilization of men, machines and materials by maintaining a free flow of materials along the production line.

a) Production
b) Scheduling
c) Assembling
d) Material Flow

Q.18. Which of the following is not a part of Five M's?

a) Material
b) Machine
c) Motion
d) Method

Q.19. The correct sequence of operations in production planning and control is

a) Routing-Scheduling-Dispatching-Follow up
b) Scheduling-Routing- Dispatching-Follow up
c) Dispatching-Routing-Scheduling- Follow up
d) Routing-Scheduling-Follow up-Dispatching

Q.20. Loading may be defined as

a) Sending the raw material to the machine
b) Sending the finished material to the store
c) Assign the work to the facilities
d) Uploading a software in machine control panel

Q. 21. Which of the following chart is drawn Machine vs. time?

a) Man machine chart
b) The load chart
c) The progress chart
d) Curve chart

Q.22. The priority sequencing rule for job shop scheduling that does not require knowledge of job due date is:

a) Slack per remaining operations
b) Earliest due date
c) Critical ratio
d) Shortest processing time

Q.23. Advanced planning and scheduling (APS) systems seek to accomplish which of the following goals?

a) Provide an updated methodology for producing a master production schedule (MPS)
b) Enable the sharing of demand forecasts with companies in the supply chain
c) Optimize resources across the supply chain
d) Both b and c

Q.24. Planning tasks associated with job scheduling, machine loading, and dispatching typically falls under

a) long-range plans
b) intermediate-range plans
c) short-range plans
d) mission-related planning
e) strategic planning

Q. 25. In level scheduling, what is kept uniform from month to month?

a) product mix
b) inventory levels
c) demand levels
d) production/workforce levels
e) sub-contracting levels

Q. 26. The most appropriate sequencing rule to use if the goal is to dynamically track the progress of jobs and establish relative priority on a common basis is

a) shortest processing time
b) earliest due date
c) longest processing time
d) critical ratio
e) Johnson's rule

Q. 27. A recent advance in short term scheduling that makes use of expert systems and simulation in solving dynamic scheduling problems is

a) forward scheduling
b) finite scheduling
c) backward scheduling
d) infinite scheduling
e) progressive scheduling

Q. 28. Gantt chart is mostly used for

a) Routing
b) Scheduling
c) Follow up
d) Inspection and quality control

Q. 29.____________that illustrates a project schedule in which the tasks to be performed on the vertical axis, and time intervals on the horizontal axis and the width of the horizontal bars shows the duration of each activity.

a) Gantt chart.
b) Process Chart
c) Assemble Chart
d) Control Chart

Q. 30. What is a Gantt chart a type of?

a) Work flow design
b) Work schedule design
c) Work rate design
d) Work output design

Q. 31. The difference between the time available to do the job and the time required to do the job, is known as

a) Event
b) Float
c) Duration
d) Constraint

Q. 32. Templates are used for

a) A planning layout
b) Flow of material
c) Advancing a programme in automatic machines
d) Copying complicated profiles

Q. 33. Graphical method, simplex method, and transportation method are concerned with

a) Break-even analysis
b) Value analysis
c) Linear programming
d) Queueing theory

Q. 34. Which of the following is NOT true of finite loading?

a) The amount of work can be fixed.
b) The cost of limiting the load is not prohibitive.
c) It is not possible to limit the load.
d) It is necessary to limit the load.

Q. 35. When sequencing jobs, an approach which may be used to help in a cash constrained situation is:

a) First in first out (FIFO)
b) Longest operation time first (LOT)
c) Shortest operation time first (SOT)
d) Last in first out (LIFO)

Q. 36. Johnson's Rule applies to the sequencing of jobs through two work centres. It states that:

a) The job with the longest processing time for the first process should be done first and the job with the longest processing time for the second process should be done last.
b) The job with the smallest processing time for the first process should be done first and the job with the longest processing time for the second process should be done last.
c) The job with the smallest processing time for the first process should be done first and the job with the smallest processing time for the second process should be done last.
d) The job with the longest processing time for the first process should be done first and the job with the smallest processing time for the second process should be done last.

Q. 37. Which of the following is not an advantage of backward scheduling:

a) Tends to focus the operation on customer due dates.
b) Lower material costs – materials are not used until they have to be, therefore delaying added value until the last minute.
c) Less exposed to risk in case of schedule change by the customer.
d) Flexible – the time slack in the system allows unexpected work to be loaded.

Q. 38. If the operation selects a sequencing approach purely on practical reasons for an activity such as unloading cases from an aircraft, it may choose:

a) Due date
b) Last in first out
c) Shortest operation time first.
d) First in first out
e) Longest operation time first

Q. 39. If the operation selects a sequencing approach which will appear fair to its customers it may choose:

a) Shortest operation time first
b) Due date
c) Last in first out
d) First in first out
e) Longest operation time first

Q. 40. Which of the following is not type of scheduling problem?

a) Young shop
b) Single machine
c) Flow shop
d) Job Shop

Q. 41.in Single Machine Scheduling, EDD stand for;

a) Earn Daily Data
b) Emergency Desk Date
c) Early Due Date
d) Efficient Drawing Data

Q. 42. Line of Balance (LOB) is a type of Scheduling Technique.

a) True
b) False
c) Partly True
d) None of the Above

Q. 43. Routing prescribes the

a) Flow of material in the plant
b) Proper utilization of man power
c) Proper utilization of machines
d) Inspection of final product
e) None of the above.

Q. 44. When encountering bottlenecks in a process, the AGV generally responds in what manner?

a) Fixes the problem causing the bottleneck
b) Reroutes materials to alternative workstations
c) Halts the process and sounds an alarm
d) None of the above

Q. 45. Which materials-processing technology gives the advantage of precision, accuracy and optimum use of cutting tools, which maximise their life and higher labour productivity?

a) Computer-integrated manufacturing (CIM)
b) Industrial robots

c) Flexible manufacturing systems (FMS)
d) NC (and CNC) machine tools

Q. 46. Shop loading

a) Means the assignment of jobs to work or processing centers.
b) Means the assignment of dates to specific jobs or operations steps.
c) Is oriented toward the management of work-in-process inventories.
d) Is typically managed using an assembly chart.

Q. 47. When using the critical ratio (CR) to develop a sequence

a) A CR of less than 1.0 means that the job is ahead of schedule.
b) A CR of greater than 1.0 means that the job has some slack.
c) A CR of 1.0 means that the job should be scheduled last.
d) A CR of 1.0 means that the job should be scheduled first.

Q. 48. Which of these statements regarding service scheduling is best?

a) Scheduling emphasis is on machines and material.
b) Demand for labor is stable in a service system.
c) Inventories can be used to smooth demand just like in manufacturing.
d) Behavioral, social, and status issues are important in scheduling labor.

Q. 49. Typical FMS Benefits includes;

a) Reduced work-in-process due to continuous production rather than batch production
b) Lower manufacturing lead times
c) Greater flexibility in production scheduling
d) All of the Above

Q. 50. Which is of the following is not class of production systems based on the arrangement of machines?

a) single machine shops
b) flow shops
c) job shops
d) none of the above

Answers

Module-1		Module-2		Module-3	
Q1	b	Q1	c	Q1	b
Q2	a	Q2	a	Q2	b
Q3	a	Q3	a	Q3	d
Q4	c	Q4	a	Q4	a
Q5	b	Q5	b	Q5	d
Q6	c	Q6	b	Q6	a
Q7	b	Q7	c	Q7	b
Q8	a	Q8	d	Q8	d
Q9	b	Q9	c	Q9	c
Q10	b	Q10	a	Q10	c
Q11	b	Q11	a	Q11	d
Q12	c	Q12	a	Q12	c
Q13	b	Q13	a	Q13	c
Q14	b	Q14	d	Q14	a
Q15	a	Q15	a	Q15	a
Q16	b	Q16	b	Q16	a
Q17	b	Q17	d	Q17	b
Q18	e	Q18	c	Q18	c
Q19	a	Q19	d	Q19	a
Q20	b	Q20	d	Q20	c
Q21	a	Q21	b	Q21	b
Q22	c	Q22	b	Q22	d
Q23	a	Q23	e	Q23	d
Q24	d	Q24	d	Q24	c
Q25	a	Q25	d	Q25	d
Q26	c	Q26	d	Q26	d
Q27	d	Q27	b	Q27	b
Q28	c	Q28	a	Q28	b
Q29	c	Q29	a	Q29	a
Q30	c	Q30	c	Q30	b
Q31	d	Q31	a	Q31	b
Q32	c	Q32	d	Q32	a
Q33	b	Q33	d	Q33	c
Q34	c	Q34	d	Q34	c
Q35	c	Q35	c	Q35	c
Q36	b	Q36	a	Q36	c
Q37	a	Q37	b	Q37	d
Q38	a	Q38	d	Q38	b
Q39	c	Q39	a	Q39	d
Q40	b	Q40	c	Q40	d
Q41	d	Q41	b	Q41	b
Q42	a	Q42	d	Q42	a
Q43	a	Q43	a	Q43	a
Q44	a	Q44	e	Q44	b
Q45	a	Q45	c	Q45	d
Q46	d	Q46	a	Q46	a
Q47	c	Q47	b	Q47	b
Q48	a	Q48	c	Q48	d
Q49	d	Q49	e	Q49	d
Q50	c	Q50	c	Q50	d

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