INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

MECHANICAL ENGINEERING

COURSE LECTURE NOTES

Course Name	**PRODUCTION PLANNING AND CONTROL**
Course Code	AME518
Programme	B.Tech
Semester	VIII
Course Coordinator	Mr. V. Mahidhar Reddy, Assistant Professor
Course Faculty	Mr. V. Mahidhar Reddy, Assistant Professor
Lecture Numbers	1-52
Topic Covered	All

COURSE OBJECTIVES (COs):

The course should enable the students to:	
I	Understand the PPC function in industrial manufacturing scenario.
II	Apply forecasting techniques for different types of products.
III	Knowledge in optimal inventory control and capacity planning.

COURSE LEARNING OUTCOMES (CLOs):

Students, who complete the course, will have demonstrated the ability to do the following:

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AMEB518.01	CLO 1	Understand the core features of the operations	PO 1	3
AMEB518.02	CLO 2	Understand production management function at the operational and strategic levels	PO 2	2
AMEB518.03	CLO 3	specifically the relationships between people	PO 1	3
AMEB518.04	CLO 4	Evaluate operational and strategic levels	PO 1	3
AMEB518.05	CLO 5	Solve problems on operational and strategic management	PO 2	2

AMEB518.06	CLO 6	Production management basics and its history	PO 2	2
AMEB05.07	CLO 7	Key issues on market-driven systems and global competition	PO 2	2
AMEB518.08	CLO 8	Classification of production systems, and their definitions	PO 2	2
AMEB518.09	CLO 9	Classification of planning and control problems, and their definitions	PO 4	1
AMEB518.10	CLO 10	Problem solving procedure	PO 4	1
AMEB518.11	CLO 11	Demand forecasting and market analysis	PO 2	2
AMEB518.12	CLO 12	Qualitative approaches to forecasting	PO 2	2
AMEB518.13	CLO 13	A variety of quantitative forecasting techniques including the use of computer tools	PO 1	3
AMEB518.14	CLO 14	Decomposition of data into its components	PO 1	3
AMEB518.15	CLO 15	The systems perspective to production planning problems and to integrate different production planning activities	PO 1	3
AMEB518.16	CLO 16	Formulation of aggregate planning problems; their objectives, constraints and applicable solution techniques	PO 1, PO 2	3
AMEB518.17	CLO 17	Surveying, gathering and analysis of data for planning purposes	PO 1, PO 2	3
AMEB518.18	CLO 18	Solving basic production planning problems	PO 1, PO 2	3
AMEB518.19	CLO 19	Solving basic inventory management problems, Importance of accuracy in estimating market share, demand, relevant costs and all requirements and the sensitivity of results to these values	PO 1,	3

SYLLABUS

UNIT-I	**OVERVIEW OF PRODUCTION PLANNING CONTROL**	**Classes : 09**
Introduction: Definition, Objectives of production planning and control, functions of production planning and control, elements of production control, types of production, organization of production planning and control department, internal organization of department.		
UNIT-II	**FORECASTING**	**Classes : 09**
Forecasting: Importance of forecasting, types of forecasting, their uses, general principles of forecasting, forecasting techniques, qualitative methods and quantitive methods; Inventory management, functions of inventories relevant inventory costs ABC analysis, VED analysis, EOQ model, inventory control systems, P-Systems and Q-Systems.		
UNIT-III	**INTRODUCTION TO MRP**	**Classes: 09**
Introduction to MRP and ERP, LOB (Line of Balance), JIT inventory, and Japanese concepts. Routing, definition, routing procedure Route sheets, bill of material, factors affecting routing procedure, Schedule, definition, difference with loading.		
UNIT-IV	**SCHEDULING**	**Classes: 09**
Scheduling Policies, techniques, Standard scheduling methods; Line balancing, aggregate planning, chase planning, expediting, controlling aspects.		

UNIT-V	DISPATCHING	Classes : 09
Dispatching: Activities of dispatcher, dispatching procedure, followup, definition, reason for existence of functions, types of followup, applications of computer in production planning and control.		
Text Books:		
1. M. Mahajan, ‒Production Planning and Control‖, Dhanpat Rai, 1st Edition, 2010. 2. Jain, Jain, ‒Production planning and control‖, Khanna Publications, 1st Edition, 2012.		
Reference Books:		
1. S. N. Chary, ‒Operations Management‖, Tata McGraw-Hill, 5th Edition, 2013. 2. Chase, ‒Operation Management‖, PHI, 1st Edition, 2013.		

UNIT-1
OVERVIEW OF PRODUCTION PLANNING CONTROL

Introduction

Production function is that part of an organization, which is concerned with the transformation of a range of inputs into the required outputs (products) having the requisite quality level. Production may be understood as "the step-by-step conversion of one form of material into another form through chemical or mechanical process to create or enhance the utility of the product to the user. Thus production is a value addition process.

In any manufacturing enterprise, the main objective of production department is to produce the things in desired quantity at desired time so that they may be made available to end users when they demand it. Production, being a very complex process is very difficult to manage for the people. This includes a large number of activities and operations which need to be planned appropriately and in turn controlled for the effective production of the output. The main purpose of production planning and control (PPC) is to establish routes and schedules for the work that will ensure the optimum utilization of materials, workers, and machines and to provide the means for ensuring the operation of the plant in accordance with these plans.

There are different types of production systems. The choice of production system depends upon the nature of products, variety of products and volume of products. These production systems have been discussed in this chapter in detail. Entrepreneurs, after finalizing the production system to be used are required to go for the production planning and control (PPC) which essentially depends upon the type of production system.

Production planning and control is necessarily concerned with implementing the plans, i.e. the detailed scheduling of jobs, assigning of workloads to machines (and people), the actual flow of work through the system. Production is an organized activity of converting row materials into useful products. Production system requires the optimal utilization of natural resources like men, money, machine, materials and time. Production planning and control coordinate with different departments: such as production, marketing, logistics, warehouse and other departments depending upon the nature of

organization. Production planning and control receives data related to orders from marketing departments. Production plan based on marketing and production data is prepared in production planning and control. This production plan provides clear idea about utilization of manufacturing resources for production. Prepared production plan is delivered to production department. Production department manufacture products according to that plan.

The ultimate objective of production planning and control, like that of all other manufacturing controls, is to contribute to the profits of the enterprise. As with inventory management and control, this is accomplished by keeping the customers satisfied through the meeting of delivery schedules.

The main objectives of PPC may be summarized as followings:-

a) It is used to establish target and check the deviations by comparing on some performance measures.
b) Decides the nature and magnitude of different input factors to produce the output.
c) Coordinates different resources of production system in the most effective and economic manner and to coordinate among different departments.
d) Elimination of bottleneck
e) Utilization of inventory in the optimal way
f) Smooth flow of material
g) To produce in right quantity and quality at right time
h) Scheduling production activities to meet delivery schedule
i) Expediting the system under production
j) To ensure flexibility in production system to accommodate changes and uncertainty
k) Optimizes the use of resources for minimum overall production cost
l) To ensure the production of right product at right time in right quantity with specification rightly suited to customers
m) Stable production system, with least chaos, confusion and undue hurry.

This chapter deals in detail with the concept of production planning and control. This will help the students to understand the PPC to be used for the different types of production systems along with their merits and demerits. This will also make them familiar with

various constraints in PPC.

Meaning of Production

As discussed earlier, production refers to the transformation of inputs into finished goods/ or creation of services in order to satisfy the customer needs. This uses different inputs mainly including 6M's namely, man, material, machine, money, method and management. Production involves application of processes by which the inputs can be transformed into desired product (output) of potential utility while improving properties and adding economic values through the best method without compromising on quality.

Different forms of production based on the processes used:

1. Production by extraction or separation: like petrol, kerosene, sugar etc
2. Production by assembly: car, television, furniture

Edwood Buffa defines production as "a process by which goods and services are created" Some examples of production are: manufacturing custom-made products like, boilers with a specific capacity, constructing flats, some structural fabrication works for selected customers etc. At each stage of processing, there will be value addition. It is easy to understand a production system from the figure 1.1. There are various inputs which essentially pass through a transformation/ conversion process and finally converted into some outputs which have a value for the end users.

The outputs may be in the form of tangible products or services. In nutshell, production system of an organization is that part, which produces products of an organization. It is that activity whereby resources, flowing within a defined system, are combined and transformed in a controlled manner to add value in accordance with the policies communicated by management. A simplified production system is shown above.

etc., and manufacturing standardized products like, car, bus, motor cycle, radio, television, etc.

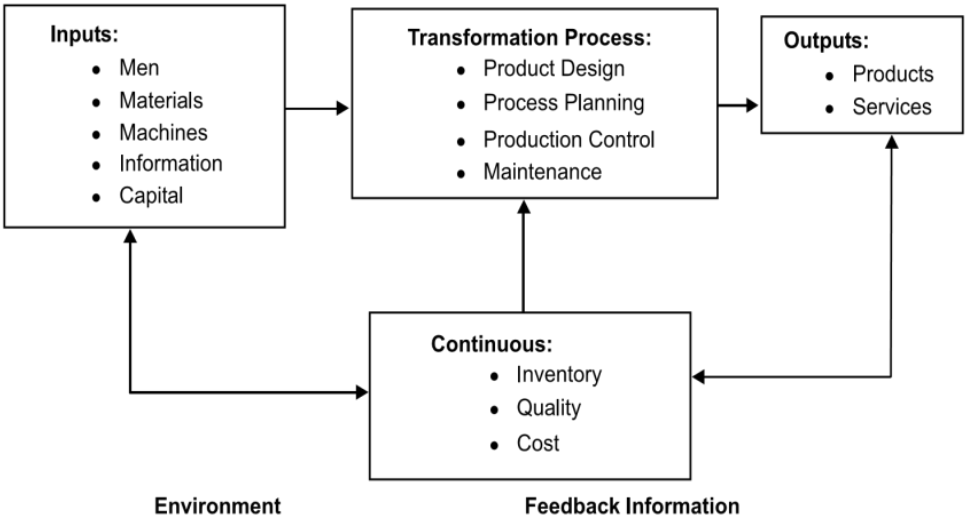


Fig. 1.1 *Schematic production system*

Production management involves the managerial decisions regarding design of the product and design of the production system i.e. determination of production processes and production planning and control.

Blueprint of Production system

An enterprise in the beginning needs to define its production system that is considered as the framework within which all production related activities and operations take place. Manufacturing process is the transformation process through which inputs are converted into outputs. An appropriate designing of production system ensures the coordination of various production activities and operations. There is no single pattern of production system which is universally applicable in all kinds of enterprises. This varies from one enterprise to another depending upon many parameters.

Types of Production systems

There are mainly three types of production systems mentioned as below:

(1) Continuous/Mass production
(2) Job or unit production
(3) Intermittent/Batch production

(1) **Continuous/Mass production:** It is used when we need to produce standardized

products with a standard set of process and operation sequence in anticipation of demand. This ensures continuous production of output. It is also termed as mass flow production or assembly line production. This system results in less work in process (*wip*) inventory and high product quality but involves high capital investment in machinery and equipment. This ensures very high rate of production as we need not to intervene once the production has begun. The system is appropriate in plants where large volume of small variety of output is produced. e.g. oil refineries, cement manufacturing and sugar factory etc.

Characteristics of Continuous/Mass production:

a) As same product is manufactured for sufficiently long time, machines can be laid down in order of processing sequence.
b) Standard methods and machines are used during part manufacture.
c) Most of the equipment's are semi automatic or automatic in nature.
d) Material handling is also automatic (such as conveyors).
e) Semi-skilled workers are normally employed as most of the facilities are automatic.
f) As product flows along a pre-defined line, planning and control of the system is much easier.
g) Cost of production per unit is very low owing to the high rate of production.
h) In process inventories are low as production scheduling is simple and can be implemented with ease.

(2) **Job or Unit production:** It involves production as per customer's specifications. This ensures the simultaneous production of large number of batches/orders. Each batch or order comprises of a small lot of identical products and is different from other batches. It requires comparatively smaller investment in machines and equipment. It is flexible and can be adapted to changes in product design and order size without much inconvenience. This system is most suitable where heterogeneous products are produced against specific orders. In this system products are made to satisfy a specific order. However that order may be produced- only once or at irregular time intervals as and when new order arrives or at regular time intervals to satisfy a continuous demand.

Characteristics of Job or Unit Production:

a) Machines and methods employed should be general purpose as product changes are quite frequent.
b) Man power should be skilled enough to deal with changing work conditions.
c) Schedules are actually nonexistent in this system as no definite data is available on the product. In process inventory will usually be high as accurate plans and schedules do not exist.
d) Product cost is normally high because of high material and labor costs.
e) Grouping of machines is done on functional basis (i.e. as lathe section, milling section etc.) This system is very flexible as management has to manufacture varying product types. Material handling systems are also flexible to meet changing product requirements.

(3) **Intermittent/Batch Production:** This is concerned with the production of different types of products in small quantities usually termed as batches. A batch contains the similar products but in small quantity. This is used to meet a specific order or to meet a continuous demand. Batch can be manufactured either- only once or repeatedly at irregular time intervals as and when demand arise or repeatedly at regular time intervals to satisfy a continuous demand. Under this system the goods may be produced partly for inventory and partly for customer's orders. For example, components are made for inventory but they are combined differently for different customers. e.g. automobile plants, printing presses, electrical goods plant are examples of this type of manufacturing.

Characteristics of Intermittent/ Batch Production:

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

f) Semi-automatic material handling systems are most appropriate in conjunction with the semi-automatic machines.

In addition to the above, a large number of manufacturing plants include both intermittent and continuous processes and are classified as *composite or combination operations* .Such a plant may have sub assembly departments making parts in a continuous operation, while the final assembly department works on an intermittent basis.(as in the furniture and custom packaging industries)

Types of Manufacturing Processes

The above mentioned production systems require different types of manufacturing process and require different conditions for their working. Selection of manufacturing process is a strategic decision as any change in the same is very costly and time consuming affair. Therefore the manufacturing process is selected at the stage of planning a business venture. This must be selected keeping in view two important parameters (1) meeting the specification of the final product and (2) to be cost effective.

The manufacturing process is classified into four types.

(i) Jobbing manufacturing process
(ii) Batch manufacturing process
(iii) Mass or flow manufacturing process
(iv) Process type manufacturing process

(i) **Jobbing manufacturing process:** This is used to produce one or few units of the products as per the requirement and specification of the customer. Production is to meet the delivery schedule and costs are fixed prior to the contract made with the customer.

(ii) **Batch manufacturing process:** This is used to produce limited quantities of each of the different types of products in the form of batches. These batches of different products are manufactured on same set of machines. Different batches/products are produced separately one after the other.

(iii) **Mass or flow manufacturing process:** This is used to produce a large quantity of same product at a time that is stocked for sale. All machines and required

equipments are arranged according to the sequence of operations; termed as line arrangement/flow. This ensures very high rate of production. One line arrangement can produce only one type of product, therefore, a different line arrangement is needed for a different product.

(iv) **Process type manufacturing process:** This is used to produce the products which need a particular process/definite sequence of operations. E.g. petroleum. In this, production run is conducted for an indefinite period.

Factors affecting the Choice of Manufacturing Process

Following factors need to be considered before making a choice of manufacturing process.

a) **Effect of volume/variety:** This is one of the major considerations in selection of manufacturing process. When the volume is low and variety is high, intermittent process is most suitable and with increase in volume and reduction in variety continuous process become suitable. The following figure indicates the choice of manufacturing process as a function of volume and variety.

systems.

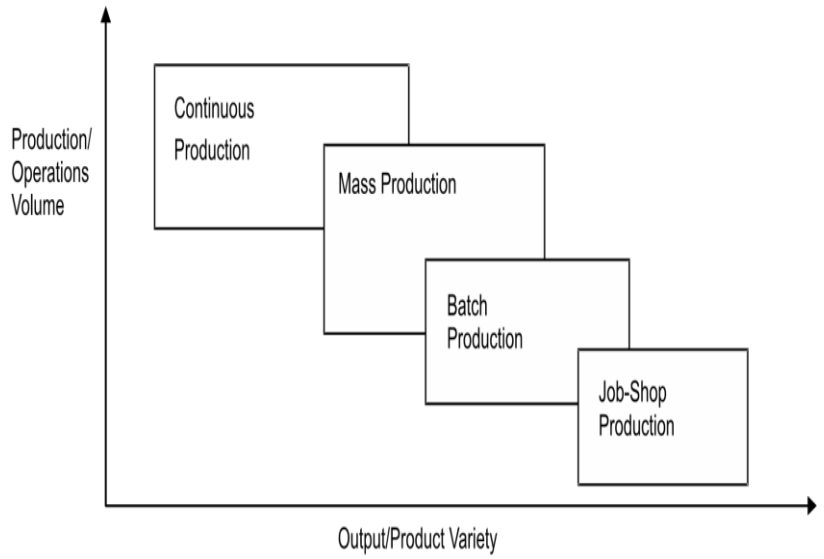


Fig. 1.2 *Classification of production systems*

b) **Capacity of the plant:** Predicted sales volume is the key factor to make a choice between batch and line process. In case of line process, fixed costs are substantially higher than variable costs. The reverse is true for batch process thus at low volume it would be cheaper to install and maintain a batch process and line process becomes economical at higher volumes.

c) **Lead time:** The continuous process normally results faster deliveries as compared to batch process. Therefore lead-time and level of competition certainly influence the choice of production process.

d) **Flexibility and Efficiency:** The manufacturing process needs to be flexible enough to adapt contemplated changes and volume of production should be large enough to lower costs.

Hence it is very important for entrepreneur to consider all above mentioned factors before taking a decision pertaining to the type of manufacturing process to be adopted. As far as Small Scale Enterprises are concerned, they usually adopt batch processes due to less volume of production and low investment.

Once the entrepreneur has made a final choice pertaining to the product design, production system and process, his next critical decision is the production and planning control (PPC) decision.

Meaning of Production Planning and Control:

PPC is a very critical decision which is necessarily required to ensure an efficient and economical production. Planned production is an important feature of any manufacturing industry. Production planning and control (PPC) is a tool to coordinate and integrate the entire manufacturing activities in a production system. This essentially comprises of planning production before actual production activities start and then exercising control over those activities sto ensure that the planned production is realized in terms of quantity, quality, delivery schedule and cost of production.

According to Gorden and Carson, PPC usually involve the organization and planning of manufacturing process. Principally, it includes entire organization. The various activities involved in production planning are designing the product, determining the equipment

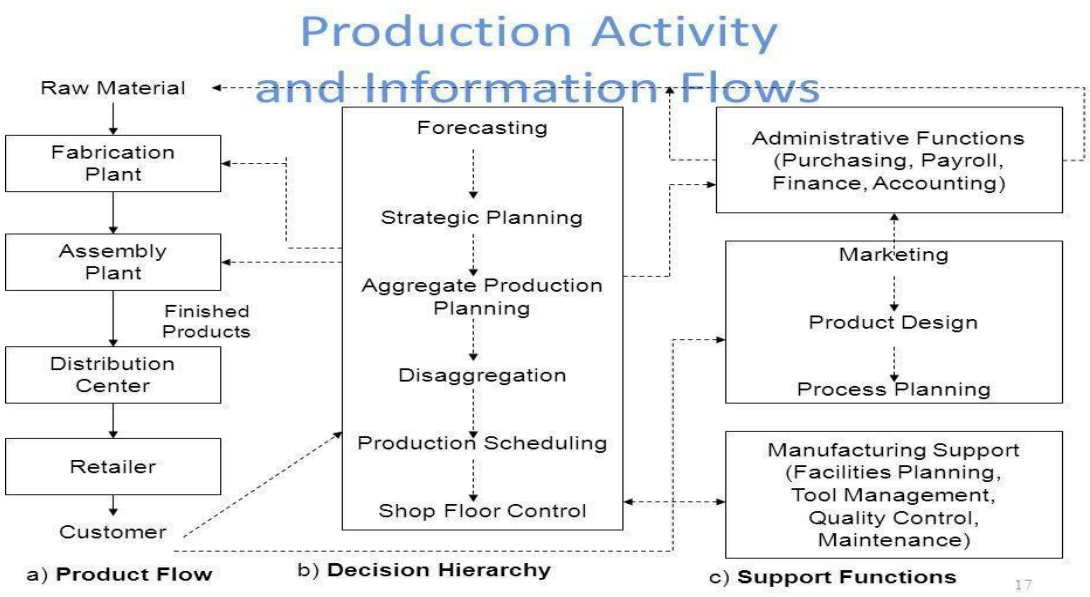
and capacity requirement, designing the layout of physical facilities and material and material handling system, determining the sequence of operations and the nature of the operations to be performed along with time requirements and specifying certain production and quantity and quality levels.

Production planning also includes the plans of routing, scheduling, dispatching inspection, and coordination, control of materials, methods machines, tools and operating times. Its ultimate objective is the to plan and control the supply and movement of materials and labour, machines utilization and related activities, in order to bring about the desired manufacturing results in terms of quality, quantity, time and place. This provides a physical system together with a set of operating guidelines for efficient conversion of raw materials, human skills and other inputs to finished product.

Procedure of Production Planning and Control

The PPC is entirely based on the pre-design format. It attempts to execute and implement all activities/operations according to the set plan. All operations should be executed in a proper manner with a close vigil on all facts ensuring that the time period and the stipulated costs should not go beyond the reach and it should be done under the excepted/agreed policies. These costs are including the cost of assets, capital cost of the facility, and labour. The PPC consists of the following steps.

a) Forecasting the demands of the customers for the products and services.
b) In advance preparing the production budget.
c) Design the facility layout.
d) Specify the types of machines and equipment.
e) Appropriate production requirements of the raw materials, labour, and machinery.
f) Drawing the apt schedule of the production.
g) Confirming the shortage or any excess of the end product.
h) Future plans are drawn for any sudden surge in the demand for the product.
i) The rate and scale of production is setup. Which needs to be broken into realistic time periods and scheduling. The specified job needs to be done in the amount of time provided so that the production can move to next step.



PPC essentially consists of three Stages:

a) Planning stage
b) Action stage
c) Monitoring stage

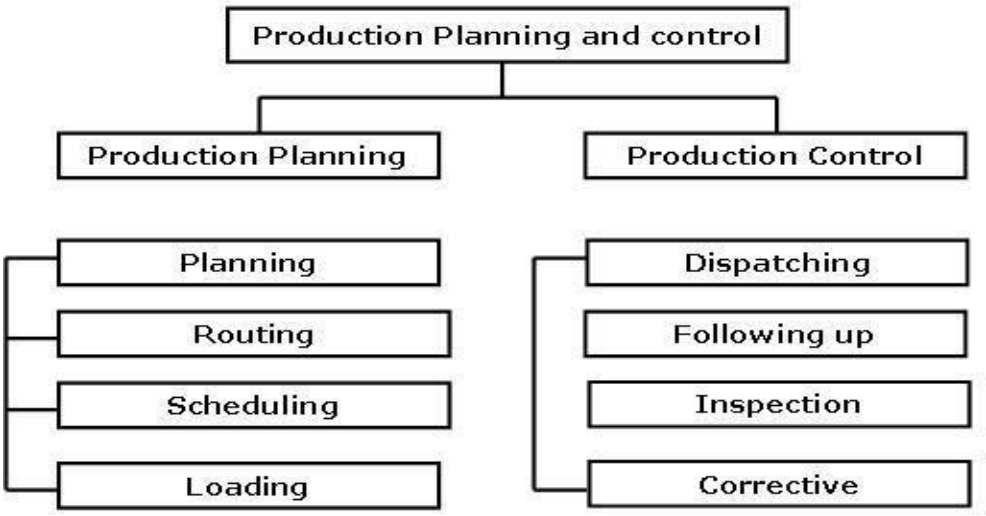
All these three stages are very important from the point of view to production because without planning no production work can take off at all. The foremost thing which is required for any production is a proper planning.

Elements of Production Planning and Control

This is important to note that production plan is the first and the foremost element of PPC. Planning refers to deciding in advance what is to be done in future. A separate planning department is established in the organization which is responsible for the preparation of policies and plans with regard to production to be undertaken in due course. The planning department prepares various charts, manuals production budgets etc., on the basis of information received from management. These plans and charts or production budgets are given practical shape by carrying various elements under production control. If production planning is defective, production control is bound to be

adversely affected. For achieving the production targets, production planning provides sound basis for production control.

One needs to remember that production plans are prepared in advance at top level whereas, production control is exercised at machine shop floor (bottom level) where actual production is taking place. Some important elements of PPC have been depicted in the figure as below:



The important elements may be listed as following:

1. **Materials:** planning for procurement of raw material, component and spare parts in the right quantities and specifications at the right time from the right source at the right place. Purchasing, storage, inventory control, standardization, variety reduction, value analysis and inspection are the other activities associated with material.
2. **Method:** choosing the best method of processing form several alternatives. It also includes determining the best sequence of operations (process plan) and planning for tooling, jigs and fixtures etc.
3. **Machines and equipment:** manufacturing methods are related to production facilities available in production systems. It involves facilities planning, capacity planning, allocations, and utilization of plant and equipment, machines etc.
4. **Manpower:** planning for manpower (labour and managerial levels) having appropriate skills and expertise.
5. **Routing;** determining the flow of work material handling in the plant, and

sequence of operations or processing steps. This is related to consideration of appropriate shop layout plant layout, temporary storage location for raw materials, component and semi-finished goods, and of materials handling system.

Route Sheet: a route sheet is a document providing information and instructions for converting the raw material in finished part or product. It defines each step of the production operations and lay down the precise path or route through which the product will flow during the conversion process. Route sheet contains following information:

a) The operation required at their desired sequence
b) Machines or equipment to be used for each operations
c) Estimated set-up time and operation time per piece
d) Tools, jigs, and fixtures required for operations
e) Detailed drawings of the part, sub-assemblies and final assemblies
f) Specification, dimensions, tolerances, surface finishes and quality standard to be achieved
g) Specification of raw material to be used
h) Speed, feed etc. to be used in machines tools for operations to be carried on.
i) Inspection procedure and metrology tools required for inspection
j) Packing and handling instructions during movement of parts and subassemblies through the operation stages.

6. **Estimating:** Establishing operation times leading to fixations of performance standards both for worker and machines. Estimating involves deciding the quantity of the product which needs to be produced and cost involved in it on the basis of sale forecast.

   Estimating manpower, machine capacity and material required meeting the planned production targets are like the key activities before budgeting for resources.

7. **Loading:** machine loading is the process of converting operation schedule into practices in conjunctions with routing. Machine loading is the process assigning specific jobs to machines, men, or work centers based on relative priorities and

capacity utilization. Loading ensures maximum possible utilization of productive facilities and avoid bottleneck in production. It's important to either overloading or under loading the facilities, work centers or machines to ensure maximum utilization of resources.

8. **Scheduling:** scheduling ensure that parts and sub-assemblies and finished goods are completed as per required delivery dates. It provides a timetable for manufacturing activities.

Purpose of scheduling:

a) To prevent unbalance use of time among work and centers and department.
b) To utilize labour such a way that output is produced within established lead time or cycle time so as to deliver the products on time and complete production in minimum total cost.

9. **Dispatching:** This is concerned with the execution of the planning functions. It gives necessary authority to start a particular work which has already planned under routing and scheduling functions. Dispatching is release of orders and instructions for starting of production in accordance with routing sheet and scheduling charts.
10. **Inspection:** This function is related to maintenance of quality in production and of evaluating the efficiency of the processes, methods and labours so that improvement can be made to achieve the quality standard set by product design.
11. **Evaluating:** The objective of evaluating is to improve performance. Performance of machines, processes and labour is evaluated to improve the same.
12. **Cost control:** Manufacturing cost is controlled by wastage reduction, value analysis, inventory control and efficient utilization of all resources.

Requirements for an effective Production Planning and Control

In an organization, PPC system can be effective only if the following aspects are given due considerations before implementation:

a) Appropriate organization structure with sufficient delegation of authority and responsibility at various levels of manpower.

b) Right person should be deputed at right place for right job.
c) Maximum level of standardization of inventory, tooling, manpower, job, workmanship, equipment, etc.
d) Appropriate management decision for production schedule, materials controls, inventory and manpower turnover and product mix.
e) Flexible production system to adjust any changes in demand, any problem in production or availability of materials maintenance requirements, etc
f) Estimation of accurate leads times for both manufacturing and purchase.
g) Management information system should be reliable, efficient and supporting.
h) Capacity to produce should be sufficient to meet the demand.
i) The facility should be responsive enough to produce new products change of products mix and be able to change the production rates.

The above elements are very important and necessary to make the production planning system effective and efficient.

Utility of PPC Productions

The implementation of PPC based production system yields various advantages to any organization for various functional activities, which include the following:

a) **Last hour rush is avoided:** Production is well planned and controlled as per the given time schedules. Therefore, production control reduces the number of emergency order and overtime works on plant and thus reduces the overheads.
b) **Problems areas of bottleneck get reduced:** The incomplete work or work-in-transit does not get piled up because production control balances the line and flow of work.
c) **Cost reduction:** An appropriate production control increases the men-machines utilization, which maintains in process inventories at a satisfactory level, leads to a better control on raw material inventories, reduces costs of storage and materials

handling, helps in maintaining quality and limits rejections and thus ultimately reduces the unit cost of production.

d) **Optimum utilization of resources:** It reduces the time loss of the workers waiting for materials and makes most effectives use of equipment.
e) **Better coordination of plants activities:** PPC coordinates the activities of the plant that leads to control concerted effort by workforce.
f) **Benefits to workers:** PPC results into better efficiency and productivity, which leads to adequate wages stable employment, job security, improved working conditions increased job satisfaction and ultimately high morale.
g) **Improved services to customers:** PPC leads to better services to the customers as it ensures production in accordance with the time schedules and therefore, deliveries are made as per the committed schedules.

Scope of Production Planning and Control

a) Nature of Inputs

To manufacture a product, different types of inputs are used. The quality of the product depends upon the nature of the inputs are used. Hence the planning is done to determine the nature of various types of inputs which is a complicated process.

b) Quantity of Inputs

To achieve a level of production, determination of quantity of the inputs and their composition is very important. A product can be prepared only when there is an estimate of the required composition of inputs.

c) Proper Coordination

It ensures the proper coordination among the workforce, machines and equipment. This leads to avoidance of wastages and smooth flow of production.

d) Better Control

Production planning is the method of control. For a better control, planning is a precondition. Only then, one can compare the performance and calculate the deviations which lead control of the production.

e) Ensure Uninterrupted Production

The planning of materials ensures the regular supply of raw materials and other components. The regular flow of materials and supplies are helpful in the uninterrupted production.

f) Capacity Utilization

There is a need to use the available resources effectively. It is helpful in bringing down various costs of production.

g) Timely Delivered

If there is good production planning and control, there will be timely production and the finished product will be rushed to the market in time. This also ensures the better relationship with the customers.

Factors affecting Production Planning and control

a) Use of Computers: Modern factories are using office automation equipment like PC, punch cards etc. It helps accurate computation of required of men and machine.
b) Seasonal Variations: Demand of certain products is affected by seasons, for instance umbrellas and raincoats during the monsoons and outputs. Production planning and control must take such changes into consideration while planning and control activities of inputs and outputs.
c) Test Marketing: In an aggressive marketing strategy new products are to be test marketed in order to know the trends. This is a short- cycle operation, intermittent in nature and often upsets regular production.
d) After Sales Service: This has become an important parameter for success. In after sales services, many items are returned for repair. These are unscheduled Work and also overload the production line.
e) Losses due to Unpredictable Factors: Losses occur due to accidents, fire and theft of production inputs, mainly materials and Components. These are unpredictable. Shortage of input due to such factors upset the planned production schedule in time and quantity.

f) Losses due to Predictable Factors: There are losses of inputs, due to natural engineering phenomena like production losses and changes in consumption of materials and occurrence of defectives.

Summary

Production function in a manufacturing organization is concerned with the transformation of some inputs into some outputs that have some value for the end users. There are many types of production systems namely mass, process, batch and job production systems. The selection of system depends upon mainly two things: i) nature of the product, ii) type of manufacturing process.

Production planning and control can be viewed as nervous system of the production operation. This function aims at efficient utilization of material resources, people and facilities in any undertaking through planning, coordinating and controlling the production activities that transform the raw material into finished products or components as a most optimal manner. All the activities in manufacturing or production cycle must be planned, coordinated, organized and controlling to its objectives. Production planning and control as a department plays a vital role in manufacturing organizations. It is clear from name that it is something about planning. Planning is defined as setting goals. Production planning and control provides different kinds of information to different departments. It provides information about available manufacturing resources to marketing department. Marketing department receives orders according to that information. Similarly, it coordinates with other departments and provides relevant information.

Production planning being a managerial function is mainly concerned with the following important issues:

a) What production facilities are required?
b) How these production facilities should be laid down in the space available for production?
c) How they should be used to produce the desired products at the desired rate of production?

Broadly speaking, production planning is concerned with two main aspects: (i) routing or planning work tasks (ii) layout or spatial relationship between the resources. Production planning is dynamic in nature and always remains in fluid state as plans may have to be changed according to the changes in circumstances.

Production control is a mechanism to monitor the execution of the plans. It has several important functions:

a) Making sure that production operations are started at planned places and planned times.
b) Observing progress of the operations and recording it properly.
c) Analyzing the recorded data with the plans and measuring the deviations.
d) Taking immediate corrective actions to minimize the negative impact of deviations from the plans.
e) Feeding back the recorded information to the planning section in order to improve future plans.

Self assessment Question

a) Discuss the different types of production systems.
b) Explain the parameters that must be considered before finalizing the production system.
c) "Effective PPC guarantees better utilization of resources". Comment on the statement with justification.
d) What do you mean by production planning? Discuss its elements.
e) Explain the utility of PPC based production.

UNIT -II

FORECASTING

Introduction

Inventory means stoke. It is essential in an organization for production activities and maintenance of plant and machinery and for other operational requirements. The normal tendency is to have more inventories so that most of the items are available when required.

Production control means controlling the production by using various methods of demand forecasting. Production control is the task of predicting, planning and scheduling work, taking into account manpower, materials availability and other capacity restrictions, and cost so as to achieve proper quality and quantity at the time it is needed

and then following up the schedule to see that the plan is carried out, using whatever systems have proven satisfactory for the purpose.

Demand forecasting is the art and science of forecasting customer demand to drive holistic execution of such demand by corporate supply chain and business management. Demand forecasting involves techniques including both informal methods, such as educated guesses, and quantitative methods, such as the use of historical sales data and statistical techniques or current data from test markets. Demand forecasting may be used in production planning, inventory management, and at times in assessing future capacity requirements, or in making decisions on whether to enter a new market

Demand forecasting is predicting future demand for the product. In other words it refers to the prediction of probable demand for a product or a service on the basis of the past events and prevailing trends in the present.

Need of Inventory

Adequate inventory ensures uninterrupted supply of finished goods and continuous production. The most significant aspect of inventory is that it should all be known and quantified. For example, we have working stock because we can’t make or buy just one every time we sell or use one. We have safety stock because of lead times, forecast errors, service requirements, etc., and our customers are unwilling to wait. We may have extra stock to buffer against supply

variability, for example because of poor vendor performance, manufacturing problems, or seasonal product availability. Lastly we could require hedge stock because we may know of a future price increase. Of course the above could occur at any level of the bill of materials, i.e., finished goods, work in process, or raw materials. For this discussion, we will concentrate just on the first two reasons for maintaining the inventories: working stock and safety stock, and just at the finished goods level. When we started in business, we concentrated at first on just the finished goods. Eventually, however, we did the research and development necessary to expand the science to address inventory at all levels

Forecasts are becoming the lifetime of business in a world, where the tidal waves of change are sweeping the most established of structures, inherited by human society. Commerce just happens to the one of the first casualties. Survival in this age of economic predators requires the tact, talent and technique of predicting the future.

Forecast is becoming the sign of survival and the language of business. All requirements of the business sector need the technique of accurate and practical reading into the future. Forecasts are, therefore, very essential requirement for the survival of business. Man- agement requires forecasting information when making a wide range of decisions.

Demand forecasting is predicting future *demand* for the product. In other words it refers to the prediction of probable *demand* for a product or a service on the basis of the past events and prevailing trends in the present.

Meaning of demand forecast

A demand forecast is the prediction of what will happen to your company's existing product sales. It would be best to determine the demand forecast using a multi-functional approach. The inputs from sales and marketing, finance, and production should be considered. The final demand forecast is the consensus of all participating managers. You may also want to put up a Sales and Operations Planning group composed of representatives from the different departments that will be tasked to prepare the demand forecast

The sales forecast is particularly important as it is the foundation upon which all company plans are built in terms of markets and revenue. Management would be a simple matter if business

was not in a continual state of change, the pace of which has quickened in recent years.

It is becoming increasingly important and necessary for business to predict their future prospects in terms of sales, cost and profits. The value of future sales is crucial as it affects costs profits, so the prediction of future sales is the logical starting point of all business planning.

A forecast is a prediction or estimation of future situation. It is an objective assessment of future course of action. Since future is uncertain, no forecast can be percent correct. Forecasts can be both physical as well as financial in nature. The more realistic the forecasts, the more effective decisions can be taken for tomorrow.

In the words of Cundiff and Still, "Demand forecasting is an estimate of sales during a specified future period which is tied to a proposed marketing plan and which assumes a particular set of uncontrollable and competitive forces". Therefore, demand forecasting is a projection of firm's expected level of sales based on a chosen marketing plan and environment.

Procedure to Prepare Sales Forecast:

Companies commonly use a three-stage procedure to prepare a sales forecast. They make an environmental forecast, followed by an industry forecast, and followed by a company's sales forecast, the environmental forecast calls for projecting inflation, unemployment, interest rate, consumer spending, and saving, business investment, government expenditure, net exports and other environmental magnitudes and events of importance to the company.

The industry forecast is based on surveys of consumers' intention and analysis of statistical trends is made available by trade associations or chamber of commerce. It can give indication to a firm regarding tine direction in which the whole industry will be moving. The company derives its sales forecast by assuming that it will win a certain market share.

All forecasts are built on one of the three information bases:

What people say? What
people do?
What people have done?

Types of Forecasting:

There are different basis to differentiate the forecasts.
*Forecasts can be broadly classified into**:***

(1) *Passive Forecast:* Under passive forecast prediction about future is based on the assumption that the firm does not change the course of its action.

(2) *Active Forecast:* Under active forecast, prediction is done under the condition of likely future changes in the actions by the firms.

*On the basis of 'time span', forecasting may be classified into two categories**:***

(1) Short term demand forecasting: In a short run forecast, seasonal patterns are of much importance. It may cover a period of three months, six months or one year. It is one which provides information for tactical decisions. Which period is chosen depends upon the nature of business. Such a forecast helps in preparing suitable sales policy.

(2) Long term demand forecasting: Long term forecasts are helpful in suitable capital planning. It is one which provides information for major strategic decisions. It helps in saving the wastages in material, man hours, machine time and capacity. Planning of a new unit must start with an analysis of the long term demand potential of the products of the firm.

Timescale	Type of decision	Examples
Short-term Up to 3-6 months	Operating	Inventory control Production planning, distribution
Medium-term 3-6 months - 2 years	Tactical	Leasing of plant and equipment Employment changes
Long-term Above 2 years	Strategic	Research and development, Acquisitions and mergers, Product changes

Forecasts may further be divided into two categories as below:

- *External or national group of forecast:* External forecast deals with trends in general business. It is usually prepared by a company's research wing or by outside consultants.

- *Internal or company group forecast:* Internal forecast includes all those that are related to the operation of a particular enterprise such as sales group, production group, and financial group. The structure of internal forecast includes forecast of annual sales, forecasts of products cost, forecast of operating profit, forecast of taxable income, forecast of cash resources, forecast of the number of employees, etc.

Forecasting may be classified as below at different levels:

- Macro-level forecasting
- Industry- level forecasting
- Firm- level forecasting
- Product-line forecasting

Macro-level forecasting is concerned with business conditions over the whole economy. It is measured by an appropriate index of industrial production, national income or expenditure. Industry-level forecasting is prepared by different trade associations. This is based on survey of consumers' intention and analysis of statistical trends. Firm-level forecasting is related to an individual firm. It is most important from managerial view point. Product-line forecasting helps the firm to decide which of the product or products should have priority in the allocation of firm's limited resources.

Forecast may be general or specific in nature. The general forecast may generally be useful to the firm. Many firms require separate forecasts for specific products and specific areas, for this general forecast is fragmented further into specific forecasts.

There are different forecasts for different types of products like:

- Forecasting demand for nondurable consumer goods
- Forecasting demand for durable consumer goods
- Forecasting demand for new-products

Non-Durable Consumer Goods:

These are also known as 'single-use consumer goods' or perishable consumer goods. These vanish after a single act of consumption. These include goods like food, milk, medicine, fruits, etc. Demand for these goods depends upon household disposable income, price of the commodity and the related goods and population and characteristics. Symbolically,

$Dc = f(y, s, p, p_r)$

Where;

Dc = the demand for commodity c

y = the household disposable income

s = population

p = price of the commodity c

p_r = price of its related goods

Disposable income expressed as Dc = f (y) i.e. other things being equal, the demand for commodity c depends upon the disposable income of the household. Disposable income of the household is estimated after the deduction of personal taxes from the personal income. Disposable income gives an idea about the purchasing power of the household.

Price, expressed as $Dc = f(p, p_r)$ i.e. other things being equal, demand for commodity c depends upon its own price and the price of related goods. While the demand for a commodity is inversely related to its own price of its complements. It is positively related to its substitutes. Price elasticity and cross-elasticity of non-durable consumer goods help in their demand forecasting

Population, expressed as Dc= f (5) i.e. other things being equal, demand for commodity c depends upon the size of population and its composition. Besides, population can also be classified on the basis of sex, income, literacy and social status. Demand for non-durable consumer goods is influenced by all these factors. For the general demand forecasting population as a whole is considered, but for specific demand forecasting division of

population according to different characteristics proves to be more useful.

The various steps involved in forecasting the demand for non-durable consumer goods are the following:

(i) First identify the variables affecting the demand for the product and express them in appropriate forms,

(ii) Gather relevant data or approximation to relevant data to represent the variables, and

(iii) Use methods of statistical analysis to determine the most probable relationship between the dependent and independent variables.

Durable Consumer Goods:

These goods can be consumed a number of times or repeatedly used without much loss to their utility. These include goods like car, T.V., air-conditioners, furniture etc. After their long use, consumers have a choice either these could be consumed in future or could be disposed of.

The choice depends upon the following factors:

- Whether a consumer will go for the replacement of a durable good or keep on using it after necessary repairs depends upon his social status, level of money income, taste and fashion, etc. Replacement demand tends to grow with increase in the stock of the commodity with the consumers. The firm can estimate the average replacement cost with the help of life expectancy table.

- Most consumer durables are consumed in common by the members of a family. For instance, T.V., refrigerator, etc. are used in common by households. Demand forecasts for goods commonly used should take into account the number of households rather than the total size of population. While estimating the number of households, the income of the household, the number of children and sex-composition, etc. should be taken into account.

- Demand for consumer durables depends upon the availability of allied facilities. For

example, the use of T.V., refrigerator needs regular supply of power, the use of car needs availability of fuel, etc. While forecasting demand for consumer durables, the provision of allied services and their cost should also be taken into account.

- Demand for consumer durables is very much influenced by their prices and their credit facilities. Consumer durables are very much sensitive to price changes. A small fall in their price may bring large increase in demand.

Forecasting Demand for Capital Goods:

Capital goods are used for further production. The demand for capital good is a derived one. It will depend upon the profitability of industries. The demand for capital goods is a case of derived demand. In the case of particular capital goods, demand will depend on the specific markets they serve and the end uses for which they are bought.

The demand for textile machinery will, for instance, be determined by the expansion of textile industry in terms of new units and replacement of existing machinery. Estimation of new demand as well as replacement demand is thus necessary.

Three types of data are required in estimating the demand for capital goods:

a) The growth prospects of the user industries must be known,

b) The norm of consumption of the capital goods per unit of each end-use product must be known, and

c) The velocity of their use.

Forecasting Demand for New Products:

The methods of forecasting demand for new products are in many ways different from those for established products. Since the product is new to the consumers, an intensive study of the product and its likely impact upon other products of the same group provides a key to an intelligent projection of demand.

Joel Dean has classified a number of possible approaches as follows:

- *Evolutionary Approach:* It consists of projecting the demand for a new product as an outgrowth and evolution of an existing old product.
- *Substitute Approach:* According to this approach the new product is treated as a substitute for the existing product or service.
- *Growth Curve Approach:* It estimates the rate of growth and potential demand for the new product as the basis of some growth pattern of an established product.
- *Opinion-Poll Approach:* Under this approach the demand is estimated by direct enquiries from the ultimate consumers.

- *Sales Experience Approach:* According to this method the demand for the new product is estimated by offering the new product for sale in a sample market.

- *Vicarious Approach:* By this method, the consumers' reactions for a new product are found out indirectly through the specialized dealers who are able to judge the consumers' needs, tastes and preferences.

Forecasting Techniques:

Demand forecasting is a difficult exercise. Making estimates for future under the changing conditions is a Herculean task. Consumers' behaviour is the most unpredictable one because it is motivated and influenced by a multiplicity of forces. There is no easy method or a simple formula which enables the manager to predict the future.

Economists and statisticians have developed several methods of demand forecasting. Each of these methods has its relative advantages and disadvantages. Selection of the right method is essential to make demand forecasting accurate. In demand forecasting, a judicious combination of statistical skill and rational judgment is needed.

Mathematical and statistical techniques are essential in classifying relationships and providing techniques of analysis, but they are in no way an alternative for sound judgment. Sound judgment is a prime requisite for good forecast.

The judgment should be based upon facts and the personal bias of the forecaster should not prevail upon the facts. Therefore, a mid way should be followed between mathematical techniques and sound judgment or pure guess work.

The various methods of demand forecasting can be as below:

Qualitative Methods/ Techniques:

(1) **Opinion Polling Method:** In this method, the opinion of the buyers, sales force and experts could be gathered to determine the emerging trend in the market. The opinion polling methods of demand forecasting are of three kinds:

- ✓ **Consumer's Survey Method or Survey of Buyer's Intentions:** In this method, the consumers are directly approached to disclose their future purchase plans. This is done by interviewing all consumers or a selected group of consumers out of the relevant population. This is the direct method of estimating demand in the short run. Here the burden of forecasting is shifted to the buyer. The firm may go in for complete enumeration or for sample surveys. If the commodity under consideration is an intermediate product then the industries using it as an end product are surveyed.
- ✓ **Complete Enumeration Survey:** Under the Complete Enumeration Survey, the firm has to go for a door to door survey for the forecast period by contacting all the households in the area. This method has an advantage of first hand, unbiased information, yet it has its share of disadvantages also. The major limitation of this method is that it requires lot of resources, manpower and time. In this method, consumers may be reluctant to reveal their purchase plans due to personal privacy or commercial secrecy. Moreover, at times the consumers may not express their opinion properly or may deliberately misguide the investigators.
- ✓ **Sample Survey and Test Marketing:** Under this method some representative households are selected on random basis as samples and their opinion is taken as the generalized opinion. This method is based on the basic assumption that the sample truly represents the population. If the sample is the true representative, there is likely to be no significant difference in the results obtained by the survey. Apart from that, this method is less tedious and less costly. A variant of sample survey technique is test marketing. Product testing essentially involves placing the product with a number of users for a set period. Their reactions to the product are

noted after a period of time and an estimate of likely demand is made from the result. These are suitable for new products or for radically modified old products for which no prior data exists. It is a more scientific method of estimating likely demand because it stimulates a national launch in a closely defined geographical area.

(2) **End Use Method or Input-Output Method:** This method is quite useful for industries which are mainly producer's goods. In this method, the sale of the product under consideration is projected as the basis of demand survey of the industries using this product as an intermediate product, that is, the demand for the final product is the end user demand of the intermediate product used in the production of this final product.

The end user demand estimation of an intermediate product may involve many final good industries using this product at home and abroad. It helps us to understand the relationship among various industries. In input-output accounting two matrices used are the transaction matrix and the input co-efficient matrix. The major efforts required by this type are not in its operation but in the collection and presentation of data.

(3) **Sales Force Opinion Method:** This is also known as collective opinion method. In this method, instead of consumers, the opinion of the salesmen is sought. It is sometimes referred as the "grass roots approach" as it is a bottom-up method that requires each sales person in the company to make an individual forecast for his or her particular sales territory.

These individual forecasts are discussed and agreed with the sales manager. The composite of all forecasts then constitutes the sales forecast for the organization. The advantages of this method are that it is easy and cheap. It does not involve any elaborate statistical treatment. The main merit of this method lies in the collective wisdom of salesmen. This method is more useful in forecasting sales of new products.

(4) **Experts Opinion Method:** This method is also known as *"Delphi Technique"* of investigation. The Delphi method requires a panel of experts, who are interrogated through a sequence of questionnaires in which the responses to one questionnaire are

used to produce the next questionnaire. Thus any information available to some experts and not to others is passed on, enabling all the experts to have access to all the information for forecasting.

The method is used for long term forecasting to estimate potential sales for new products. This method presumes two conditions: Firstly, the panelists must be rich in their expertise, possess wide range of knowledge and experience. Secondly, its conductors are objective in their job. This method has some exclusive advantages of saving time and other resources.

Statistical Methods/ Techniques:

Statistical methods have proved to be immensely useful in demand forecasting. In order to maintain objectivity, that is, by consideration of all implications and viewing the problem from an external point of view, the statistical methods are used.

The important statistical methods are discussed as below:

(1) **Trend Projection Method**: A firm existing for a long time will have its own data regarding sales for past years. Such data when arranged chronologically yield what is referred to as 'time series'. Time series shows the past sales with effective demand for a particular product under normal conditions. Such data can be given in a tabular or graphic form for further analysis. This is the most popular method among business firms, partly because it is simple and inexpensive and partly because time series data often exhibit a persistent growth trend.

Time series has got four types of components namely, Secular Trend (T), Secular Variation (S), Cyclical Element (C), and an Irregular or Random Variation (I). These elements are expressed by the equation O = TSCI. Secular trend refers to the long run changes that occur as a result of general tendency. Seasonal variations refer to changes in the short run weather pattern or social habits. Cyclical variations refer to the changes that occur in industry during depression and boom. Random variation refers to the factors which are generally able such as wars, strikes, flood, and food

shortage and so on.

When a forecast is made the seasonal, cyclical and random variations are removed from the observed data. Thus only the secular trend is left. This trend is then projected. Trend projection fits a trend line to a mathematical equation.

The trend can be estimated by using any one of the following methods:

a) ***The Graphical Method:*** This is the most commonly used simple technique to determine the trend. All values of output or sale for different years are plotted on a graph and a smooth free hand curve is drawn passing through as many points as possible. The direction of this free hand curve—upward or downward— shows the trend. This may be easily understood from the following table:

Sales of Firm

Year	**Sales (Rs.Crore)**
1995	40
1996	50
1997	44
1998	60
1999	54
2000	62

b) ***Least Square Method****:* Under the least square method, a trend line can be fitted to the time series data with the help of statistical techniques such as least square regression. When the trend in sales over time is given by straight line, the equation of this line is of the form: y = a + b x. Where, ‘a’ is the intercept and ‘b’ shows the impact of the independent variable. We have two variables:- the independent variable x and the dependent variable y. The line of best fit establishes a kind of mathematical relationship between the two variables .v and y. This is expressed by the regression y

on x.

In order to solve the equation $y = a + b\,x$, we have to make use of the following normal equations:

$\Sigma y = n\,a + b\,\Sigma_X$

$\Sigma x\,y = a\,\Sigma_X + b\,\Sigma^{2}_{X}$

(2) **Barometric Technique:** A barometer is an instrument to measure changes. This method is based on the notion that "the future can be predicted from certain happenings in the present." In other words, barometric techniques are based on the idea that certain events of the present can be used to predict the directions of change in the future. This is accomplished by the use of economic and statistical indicators which serve as barometers of economic change.

Generally forecasters correlate a firm's sales with three series: Leading Series, Coincident or Concurrent Series and Lagging Series:

(a) **The Leading Series:** The leading series comprise those factors which move up or down before the recession or recovery starts. They tend to reflect future market changes. For example, baby powder sales can be forecasted by examining the birth rate pattern five years earlier, because there is a correlation between the baby powder sales and children of five years of age and since baby powder sales today are correlated with birth rate five years earlier, it is called lagged correlation. Thus we can say that births lead to baby soaps sales.

(b) **Coincident or Concurrent Series:** The coincident or concurrent series are those which move up or down simultaneously with the level of the economy. They are used in confirming or refuting the validity of the leading indicator used a few months afterwards. Common examples of coinciding indicators are G.N.P itself, industrial production, trading and the retail sector.

(c) **The Lagging Series:** The lagging series are those which take place after some time lag with respect to the business cycle. Examples of lagging series are, labour cost per unit of the manufacturing output, loans outstanding, leading rate of short

term loans, etc.

(3) **Regression Analysis:** It attempts to assess the relationship between at least two variables (one or more independent and one dependent), the purpose being to predict the value of the dependent variable from the specific value of the independent variable. The basis of this prediction generally is historical data. This method starts from the assumption that a basic relationship exists between two variables. An interactive statistical analysis computer package is used to formulate the mathematical relationship which exists.

For example, one may build up the sales model as:

Magnitude of Sales = a (price) + b (advertising) + c (price of the competing product) + d (personal disposable income) + u

Where a, b, c, d are the constants which show the effect of corresponding variables as sales. The constant u represents the effect of all the variables which have been left out in the equation but having effect on sales. In the above equation, magnitude of sales is the dependent variable and the variables on the right hand side of the equation are independent variables. If the expected values of the independent variables are substituted

The regression equation can also be written in a multiplicative form as given below:

Magnitude of Sales = (Price) ^{a} + (Advertising) ^{b}+ (Price of the rival products) ^{c} + (Personal disposable income) ^{e} + u

In the above case, the exponent of each variable indicates the elasticity of the corresponding variable. Stating the independent variables in terms of notation, the equation form is $MS = P^{o.8} \times A^{o.42} \times R^{\circ.83} \times Y_2{}^{\circ.68} \times 40$

Then we can say that 1 per cent increase in price leads to 0.8 per cent change in quantum of sales and so on.

We can also take the logarithmic form of this multiple equation, and then we can write the equation in an additive form as follows:

$\log MS = a \log P + b \log A + c \log R + d \log Y_d + \log u$

In the above equation, the coefficients a, b, c, and d represent the elasticity of variables P, A, R and Y_d respectively.

The co-efficient in the logarithmic regression equation are very useful in policy decision making by the management.

(4) Econometric Models:

Econometric models are an extension of the regression technique whereby a system of independent regression equation is solved. The requirement for satisfactory use of the econometric model in forecasting is under three heads: variables, equations and data.

The appropriate procedure in forecasting by econometric methods is model building. Econometrics attempts to express economic theories in mathematical terms in such a way that they can be verified by statistical methods and to measure the impact of one economic variable upon another so as to be able to predict future events.

Utility of Forecasting:

Forecasting cuts the risk associated with business fluctuations which generally produce harmful effects in business, create unemployment, induce speculation, discourage capital formation and reduce the profit margin. Forecasting is indispensable and it plays a very important part in the determination of various policies. In modem times forecasting has been put on scientific footing so that the risks associated with it have been considerably minimized and the chances of precision increased.

Forecasts in India:

In most of the advanced countries there are specialized agencies. In India businessmen are not at all interested in making scientific forecasts. They depend more on chance, luck and astrology. They are highly superstitious and hence their forecasts are not correct. Sufficient data are not available to make reliable forecasts. However, statistics alone do not forecast future conditions. Judgment, experience and knowledge of the particular trade are also necessary to make proper analysis and interpretation and to arrive at sound conclusions.

Conclusion:

Decision support systems consist of three elements: decision, prediction and control. It is, of course, with prediction that marketing forecasting is concerned. The forecasting of sales can be regarded as a system, having inputs apprises and an output.

This simplistic view serves as a useful measure for the analysis of the true worth of sales forecasting as an aid to management. In spite of all these no one can predict future economic activity with certainty. Forecasts are estimates about which no one can be sure.

Forecasting Models

One can classify the various models available for forecasting into three categories:

- *Extrapolative models:* They make use of past data and essentially prepare future estimates by some methods of extrapolating the past data. For example, the demand for soft drinks in a city or a locality could be estimated as 110 percent of the average sales during the last three months. Similarly, the sale of new garments during the festive season could be estimated to be a percentage of the festive season sales during the previous year.
- *Casual models:* It analyses data from the point view of cause-effect relationship. For instance, to the process of estimating the demand for the new houses, the model will identify the factors that could influence the demand for the new houses and establish the relationship between these factors. The factors, for example, may include real estate prices, housing finance options, disposable income of families, and cost of construction and befits derived from tax laws. Once tea relationship between these variables and the demand is established, it is possible to use it for estimating the demand for new houses.
- *Subjective judgments:* Another set of models consist of subjective judgment using qualitative data. In some cases, it could be based on quantitative and qualitative data. In several of these methods special mechanisms incorporated to draw substantially from the expertise of group of senior managers using some collective decision making framework.

Selection of a forecasting technique:
The selection of a forecasting technique depends on the following three factors:

(a) The characteristics of the decision making situation,

(b) The characteristics of the forecasting methods,

(c) Present situation

Criteria of a Good Forecasting Method:

There are thus, a good many ways to make a guess about future sales. They show contrast in cost, flexibility and the adequate skills and sophistication. Therefore, there is a problem of choosing the best method for a particular demand situation. There are certain economic criteria of broader applicability which have been discussed as follows:

(i) Accuracy:

The forecast obtained must be accurate. How is an accurate forecast possible? To obtain an accurate forecast, it is essential to check the accuracy of past forecasts against present performance and of present forecasts against future performance. Accuracy cannot be tested by precise measurement but buy judgment.

(ii) Plausibility:

The executive should have good understanding of the technique chosen and they should have confidence in the techniques used. Understanding is also needed for a proper interpretation of results. Plausibility requirements can often improve the accuracy of results.

(iii) Durability:

Unfortunately, a demand function fitted to past experience may back cost very greatly and still fall apart in a short time as a forecaster. The durability of the forecasting power of a demand function depends partly on the reasonableness and simplicity of functions fitted, but primarily on the stability of the understanding relationships measured in the past. Of course, the importance of durability determines the allowable cost of the forecast.

(iv) Flexibility:

Flexibility can be viewed as an alternative to generality. A long lasting function could be set up in terms of basic natural forces and human motives. Even though fundamental, it would nevertheless be hard to measure and thus not very useful. A set of variables whose

co-efficient could be adjusted from time to time to meet changing conditions in more practical way to maintain intact the routine procedure of forecasting.

(v) Availability:

Immediate availability of data is a vital requirement and the search for reasonable approximations to relevance in late data is a constant strain on the forecasters patience. The techniques employed should be able to produce meaningful results quickly. Delay in result will adversely affect the managerial decisions.

(vi) Economy:

Cost is a primary consideration which should be weighted against the importance of the forecasts to the business operations. A question may arise: How much money and managerial effort should be allocated to obtain a high level of forecasting accuracy? The criterion here is the economic consideration.

(vii) Simplicity:

Statistical and econometric models are certainly useful but they are intolerably complex. To those executives who have a fear of mathematics, these methods would appear to be Latin or Greek. The procedure should, therefore, be simple and easy so that the management may appreciate and understand why it has been adopted by the forecaster.

(viii) Consistency:

The forecaster has to deal with various components which are independent. If he does not make an adjustment in one component to bring it in line with a forecast of another, he would achieve a whole which would appear consistent.

In nutshell, an ideal forecasting method is one that yields returns over cost with accuracy, seems reasonable, can be formalized for reasonably long periods, can meet new circumstances adeptly and can give up-to-date results. The method of forecasting is not the same for all products.

There is no unique method for forecasting the sale of any commodity. The forecaster may try one or the other method depending upon his objective, data availability, the urgency with which forecasts are needed, resources he intends to devote to this work and type of commodity whose demand he wants to forecast.

Techniques of Inventory Control System

1. Setting up of various stock levels:

To avoid over-stocking and under stocking of materials, the management has to decide about the maximum level, minimum level, re-order level, danger level and average level of materials to be kept in the store. These terms are explained below:

a) Re-ordering level:

It is also known as 'ordering level' or 'ordering point' or 'ordering limit'. It is a point at which order for supply of material should be made.

This level is fixed somewhere between the maximum level and the minimum level in such a way that the quantity of materials represented by the difference between the re-ordering level and the minimum level will be sufficient to meet the demands of production till such time as the materials are replenished. Reorder level depends mainly on the maximum rate of consumption and order lead time. When this level is reached, the store keeper will initiate the purchase requisition.

Reordering level is calculated with the following formula:

Re-order level = Maximum Rate of consumption x max. lead time

(b) Maximum Level:

Maximum level is the level above which stock should never reach. It is also known as 'maximum limit' or 'maximum stock'. The function of maximum level is essential to avoid unnecessary blocking up of capital in inventories, losses on account of deterioration and obsolescence of materials, extra overheads and temptation to thefts etc. This level can be determined with the following formula. Maximum Stock level = Reordering level + Reordering quantity — (Minimum Consumption x Minimum re-ordering period)

(c) Minimum Level:

It represents the lowest quantity of a particular material below which stock should not be allowed to fall. This level must be maintained at every time so that production is not held up due to shortage of any material.

It is that level of inventories of which a fresh order must be placed to replenish the stock. This level is usually determined through the following formula:

Minimum Level = Re-ordering level — (Normal rate of consumption x Normal delivery period)

(d) Average Stock Level:

Average stock level is determined by averaging the minimum and maximum level of stock.

The formula for determination of the level is as follows:

Average level =1/2 (Minimum stock level + Maximum stock level)

This may also be expressed by minimum level + 1/2 of Re-ordering Quantity.

(e) Danger Level:

Danger level is that level below which the stock should under no circumstances be allowed to fall. Danger level is slightly below the minimum level and therefore the purchases manager should make special efforts to acquire required materials and stores.

This level can be calculated with the help of following formula:

Danger Level =Average rate of consumption x Emergency supply time.

(f) Economic Order Quantity (E.O.Q.):

One of the most important problems faced by the purchasing department is how much to order at a time. Purchasing in large quantities involve lesser purchasing cost. But cost of carrying them tends to be higher. Likewise if purchases are made in smaller quantities, holding costs are lower while purchasing costs tend to be higher.

Hence, the most economic buying quantity or the optimum quantity should be determined by the purchase department by considering the factors such as cost of ordering, holding or carrying.

This can be calculated by the following formula:

$Q = \sqrt{2AS/I}$

Where Q stands for quantity per order;

A stands for annual requirements of an item in terms of rupees;
S stands for cost of placement of an order in rupees; and

I stand for inventory carrying cost per unit per year in rupees.

2. Preparation of Inventory Budgets:

Organizations having huge material requirement normally prepare purchase budgets. The purchase budget should be prepared well in advance. The budget for production and

consumable material and for capital and maintenance material should be separately prepared.

Sales budget generally provide the basis for preparation of production plans. Therefore, the first step in the preparation of a purchase budget is the establishment of sales budget.

As per the production plan, material schedule is prepared depending upon the amount and return contained in the plan. To determine the net quantities to be procured, necessary adjustments for the stock already held is to be made.

They are valued as standard rate or current market. In this way, material procurement budget is prepared. The budget so prepared should be communicated to all departments concerned so that the actual purchase commitments can be regulated as per budgets.

At periodical intervals actuals are compared with the budgeted figures and reported to management which provide a suitable basis for controlling the purchase of materials,

3. Maintaining Perpetual Inventory System:

This is another technique to exercise control over inventory. It is also known as automatic inventory system. The basic objective of this system is to make available details about the quantity and value of stock of each item at all times. Thus, this system provides a rigid control over stock of materials as physical stock can be regularly verified with the stock records kept in the stores and the cost office.

4. Establishing Proper Purchase Procedures:

A proper purchase procedure has to be established and adopted to ensure necessary inventory control. The following steps are involved.

(a) Purchase Requisition:

It is the requisition made by the various departmental heads or storekeeper for their various material requirements. The initiation of purchase begins with the receipts of a purchase requisition by the purchase department.

(b) Inviting Quotations:

The purchase department will invite quotations for supply of goods on the receipt of purchase requisition.

(c) Schedule of Quotations:

The schedule of quotations will be prepared by the purchase department on the basis of quotations received.

(d) Approving the supplier:

The schedule of quotations is put before the purchase committee who selects the supplier by considering factors like price, quality of materials, terms of payment, delivery schedule etc.

(e) Purchase Order:

It is the last step and the purchase order is prepared by the purchase department. It is a written authorization to the supplier to supply a specified quality and quantity of material at the specified time and place mentioned at the stipulated terms.

5. Inventory Turnover Ratio:

These are calculated to minimize the inventory by the use of the following formula:

Inventory Turnover Ratio = Cost of goods consumed/sold during the period/Average inventory held during the period

The ratio indicates how quickly the inventory is used for production. Higher the ratio, shorter will be the duration of inventory at the factory. It is the index of efficiency of material management.

The comparison of various inventory turnover ratios at different items with those of previous years may reveal the following four types of inventories:

(a) Slow moving Inventories:

These inventories have a very low turnover ratio. Management should take all possible steps to keep such inventories at the lowest levels.

(b) Dormant Inventories:

These inventories have no demand. The finance manager has to take a decision whether such inventories should be retained or scrapped based upon the current market price, conditions etc.

(c) Obsolete Inventories:

These inventories are no longer in demand due to their becoming out of demand. Such inventories should be immediately scrapped.

(d) Fast moving inventories:

These inventories are in hot demand. Proper and special care should be taken in respect of these inventories so that the manufacturing process does not suffer due to shortage of such inventories.

Perpetual inventory control system:

In a large b essential to have information about continuous availability of different types of materials and stores purchased, issued and their balance in hand. The perpetual inventory control system enables the manufacturer to know about the availability of these materials and stores without undergoing the cumbersome process of physical stock taking.

Under this method, proper information relating to receipt, issue and materials in hand is kept. The main objective of this system is to have accurate information about the stock level of every item at any time.

Perpetual inventory control system cannot-be successful unless and until it is accompanied by a system of continuous stock taking i.e., checking the total stock of the concern 3/4 times a year by picking 10/15 items daily (as against physical stock taking which takes place once a year).

The items are taken in rotation. In order to have more effective control, the process of continuous stock taking is usually undertaken by a person other than the storekeeper. This will check the functioning of storekeeper also. The items may be selected at random to have a surprise check. The success of the system of perpetual inventory control depends upon the proper implementation of the system of continuous stock taking.

6. ABC analysis:

In order to exercise effective control over materials, A.B.C. (Always Better Control) method is of immense use. Under this method materials are classified into three categories in accordance with their respective values. Group ‘A’ constitutes costly items which may be

only 10 to 20% of the total items but account for about 50% of the total value of the stores.

A greater degree of control is exercised to preserve these items. Group 'B' consists of items which constitutes 20 to 30% of the store items and represent about 30% of the total value of stores.

A reasonable degree of care may be taken in order to control these items. In the last category i.e. group 'Q' about 70 to 80% of the items is covered costing about 20% of the total value. This can be referred to as residuary category. A routine type of care may be taken in the case of third category.

This method is also known as 'stock control according to value method', 'selective value approach' and 'proportional parts value approach'.

If this method is applied with care, it ensures considerable reduction in the storage expenses and it is also greatly helpful in preserving costly items.

Key Terms

ABC Classification: Classification of inventory in three groups: an A group comprising items with a less volume and large rupee value, a B group comprising items with moderate volume and moderate rupee value, and C group comprising items with a large volume and small volume.

Inventory refers to the materials in stock. It is also called the idle resource of an enterprise. Inventories represent those items which are either stocked for sale or they are in the process of manufacturing or they are in the form of materials which are yet to be utilized.

Inventory control is a planned approach of determining what to order, when to order and how much to order and how much to stock so that costs associated with buying and storing are optimal without interrupting production and sales

Forecasting The process of analyzing and understanding current and past information to understand the future patterns through a scientific and systemic approach is called forecasting. And the process of estimating the future demand of product in terms of a unit or monetary value is referred to as demand forecasting.

Inventory Control System is a system the encompasses all aspects of managing a company's inventories; purchasing, shipping, receiving, tracking, warehousing and storage, turnover, and reordering

Self-Assessment Question

1. Define the term "forecasting" What is its purpose? Describe the uses and limitations of weighted moving average method of forecasting.
2. Discuss critically the different models of forecasting.

3. What are the possible consequences if a large-scale firm places its product in the market without having estimated the demand for its product?
4. Explain the regression method of demand forecasting.
5. Why is demand forecasting essential? Is demand forecasting equally important for small and big; old or new business ventures.
6. What do you mean by ‘Inventory Control’?

UNIT -III

INTRODUCTION TO MRP

Material Requirements Planning is primarily related to the inventory of raw materials and components which are required to produce the products in a facility. Their demand is usually termed as secondary demand that totally depends upon the demand of finished product. The demand for the finished products is known as primary demand. This primary demand is ascertained mainly by aggregating the demand from sales orders and forecasted demand. Then, keeping in view the product structure, secondary demand that is the demand for the various components and raw materials is ascertained. There are various techniques which may be used to determine the order lot size for components and raw materials. MRP is a time phased priority-planning technique that estimates material requirements and schedules supply to meet demand across all products and parts in one or more plants. Now- a- days, information technology plays a major role in designing and implementing Material Requirements Planning systems and processes as it provides information about manufacturing needs (linked with customer demand) as well as information about inventory levels. MRP techniques focus on optimizing inventory.

Concept of Material Requirement Planning

Material Requirements Planning is basically concerned with the inventory of raw materials and components which are required to produce the products in a facility. The demand for raw materials and components is termed as secondary demand which is essentially depending upon the demand for the finished products. At current, globalization of the economy and the liberalization of the trade markets have created new conditions in the market place which are characterized by turbulence and intensive competition in the business environment. Competition is continuously growing with respect to price, quality and selection, service and promptness of delivery. Removal of barriers, international cooperation, technological innovations naturally cause competition to Intensify. In terms of manufacturing emphasis is placed on reducing cost while improving quality. In addition, other factors such as timely delivery of the product become critical *(this is captured by emphasis in Just in Time or JIT in short)* techniques.

It is a time phased priority-planning technique that estimates material requirements and schedules supply to meet demand across all products and parts in one or more plants. MRP techniques are used to explode bills of material, to compute net material requirements and plan future production.

Information Technology plays a major role in designing and implementing Material Requirements Planning systems and processes as it provides information about manufacturing needs (linked with customer demand) as well as information about inventory levels. MRP techniques focus on optimizing inventory.

MRP systems mainly use following information to determine what material should be ordered and when:-

- The master production schedule, which describes when each product is scheduled to be manufactured;
- Bill of materials, which lists exactly the parts or materials required to make each product;
- Production cycle times and material needs at each stage of the production cycle time;
- Supplier lead -times.

In figure 1, you can see the overall view of the Inputs to a Standard Material Requirements system and the various reports generated by the system which are of immense importance for the production managers.

The master schedule and bill of materials indicate what materials should be ordered; the master schedule, production cycle times and supplier lead times then jointly determine when orders need to be placed.

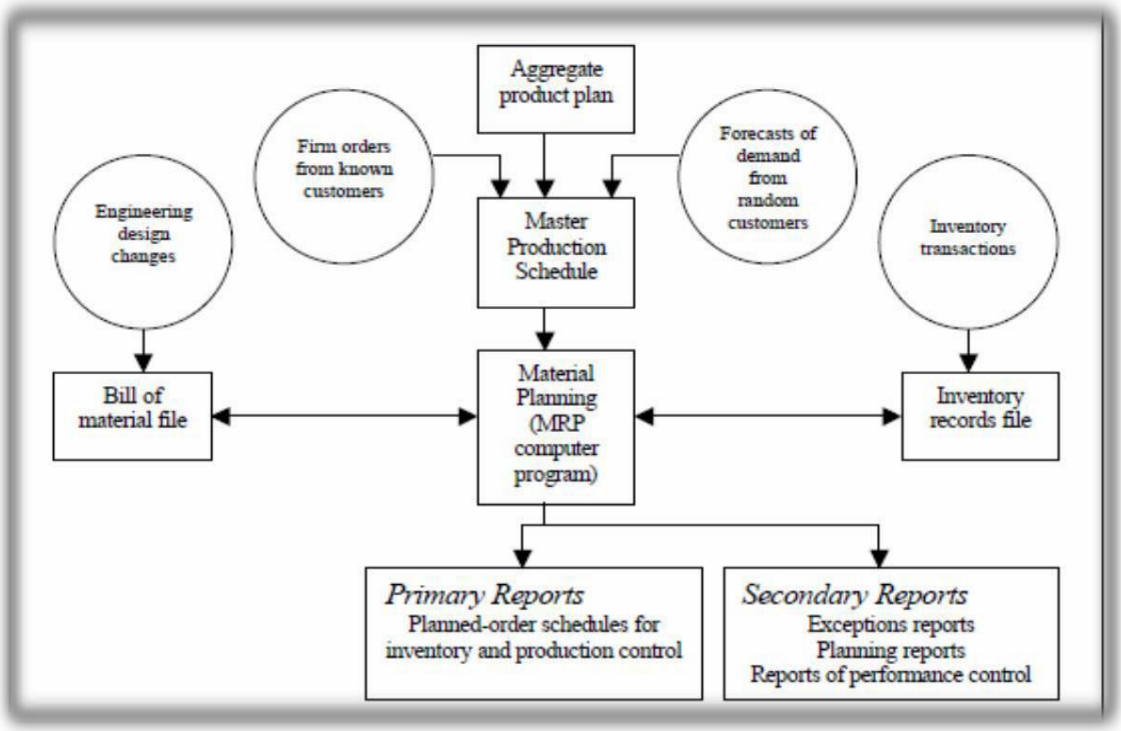


Figure 1: MRP System

The Master Production Schedule includes quantities of products to be produced at a given time period. Quantities are included both at aggregate and detailed levels. Aggregate may refer to monthly production and detailed may refer to weekly or daily production. The master production schedule is a tabular form in which rows represent products and columns represent time components.

Bill of Materials gives information about the product structure, i.e., parts and raw material units necessary to manufacture one unit of the product of interest *(discussed in next section of this chapter)*. MRP was pioneered in the 1970's with the work of Orlicky. Later evolved or became part of integrated to Manufacturing Resource Planning systems (or MRPII). MRPII is a computer based planning and scheduling system designed to improve management's control of manufacturing and its support functions.

Classes of MRP User/ Companies:

MRP systems fall into four categories, often identified as ABCD, in terms of use and organizational implementation.

I. **Class A** represents full implementation of MRP. MRP system is tied up with company "financial system and includes capacity planning, shop floor dispatching, and vendor scheduling as well as links with human resource planning. There exists continuous monitoring of performance and inventory records and master production schedules are accurate;

II. **Class B** represents a little less than full implementation. MRP system is confined in the manufacturing area; however, it includes master production scheduling;

III. **Class C** represents a classical MRP approach in which the system is confined to management of inventories;

IV. **Class D** represents a data processing application of MRP. System is used for keeping track of data rather than as decision making tool.

Conditions for the successful implementation of MRP:

MRP is most valuable to companies involved in assembly operations and least valuable to those in fabrication. For the success of MRP in an organization, some conditions need to be fulfilled as followings:

- Availability of a computer based manufacturing system is a must. Although it is possible to obtain material requirements plan manually, it would be impossible to keep it up to date because of the highly dynamic nature of manufacturing environments;
- A feasible master production schedule must be drawn up, or else the accumulated planned orders of components might "bump" into the resource restrictions and become infeasible;
- The bills of material should be accurate. It is essential to update them promptly to reflect any engineering changes brought to the product. If a component part is omitted from the bill of material it will never be ordered by the system;
- Inventory records should be a precise representation of reality, or else the netting process and the generation of planned orders become meaningless;
- Lead times for all inventory items should be known and given to the MRP system;
- Shop floor discipline is necessary to ensure that orders are processed in conformity with the established priorities. Otherwise, the lead times passed to MRP will not materialize.

Inputs and outputs in MRP System

Inputs to MRP Programme:

Product Demand- Product demand for end items stems from two main reasons. The first is known customers who have placed specific orders, such as those generated by sales personnel, or from interdepartmental transactions. The second source is forecast demand. Demand from known customers and demand forecast are combined and become the input to the master production schedule.

Bill of Materials (BOM) File- BOM file is a document which tells us about an items product structure and also it tells us about the sequence in which components are assembled and their required number. It also tells us about the workstations in which it is assembled. Bill of Materials gives information about the product structure, i.e., parts and raw material units necessary to manufacture one unit of the product of interest

Product structure

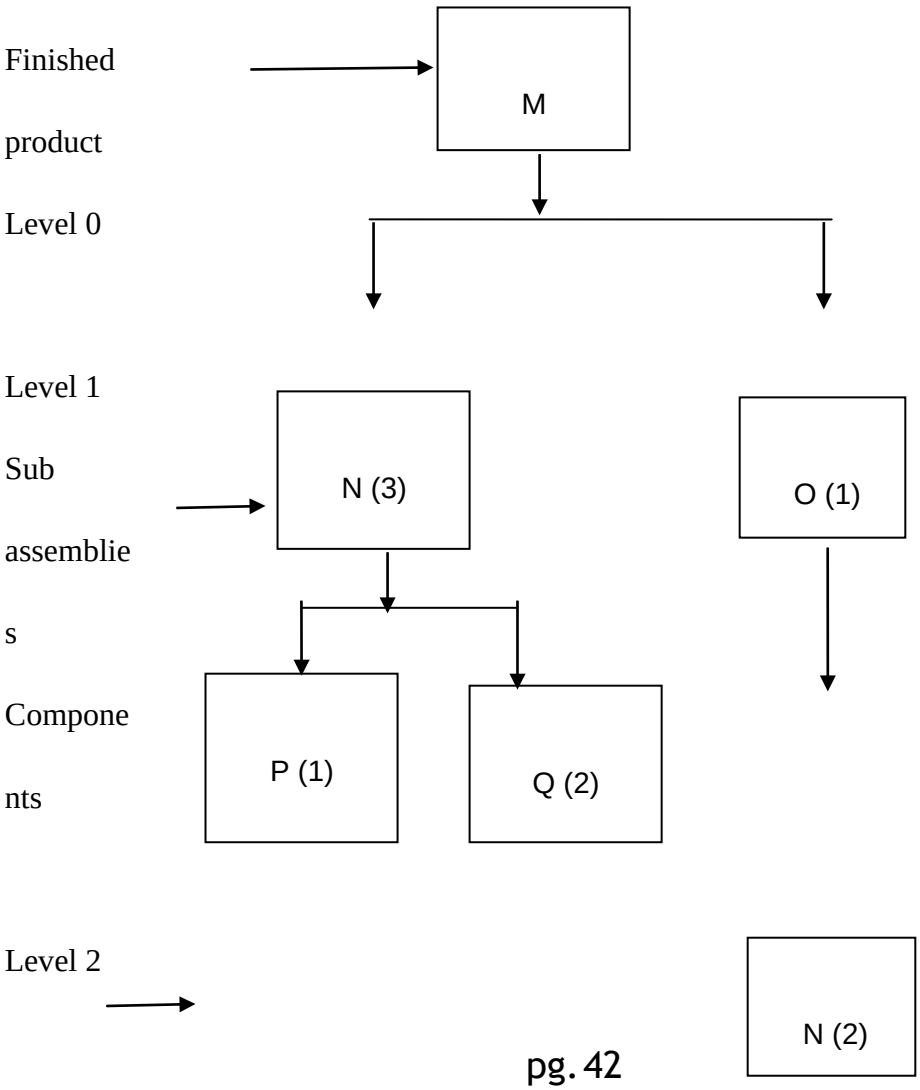
Product structure shows a product build up. Its shows diagrammatically the components required to assemble it, their numbers, and the sequence of assembly.

Example: A sub assembly A is made by joining one unit of components B and two units of components C (shown below). Therefore, if 100 units of sub assembly A are to be manufactured 100 units of component B and 200 units of components of C are required.

The BOM file is often called the product structure file or product tree because it shows how a product is put together. It contains the information to identify each item and the quantity used per unit of the item of which it is a part.

For example, the product structure of product M has been shown below. The sub assembly N appears at level 1 as well as level 2 of the product structure .when a computer program reads a bill of material of a product, it starts from the top level which is level 0 as it moves downward, it counts down the product structure tree .If an item appears in more than one level, its number of units cannot be determined unless the computer scan reaches the lowest level. This results in inefficiency of the program.

Product structure of product M



Components

Master Production Schedule- The master schedule and bill of materials indicate what materials should be ordered; the master schedule, production cycle times and supplier lead times then jointly determine when orders need to be placed. The Master Production Schedule includes quantities of products to be produced at a given time period. Quantities are included both at aggregate and detailed levels. Aggregate may refer to monthly production and detailed may refer to weekly or daily production. The master production schedule takes the form of a table in which rows represent products and columns represent time components.

Let me explain it with the help of example:

Numbers of cars to be produced by Nissan India in upcoming months:

Months	Number of Cars
Jan	10000
Feb	12000
Mar	8000
Apr	11000
May	7000
June	12000

The above table reveals the production plan of Nissan India. Master Production Schedule (MPS) tell us that how much amount of a particular model is to be manufactured in a given period of time, if the aggregate plan is given in months, MPS may be divided further into weeks. Let's take an example: Master production schedule of month January is shown below:

Weeks of January	1st	2nd	3rd	4th	Total
Model-A	1200	2000	2700	750	6650
Model-B	700	950	1100	200	2950
Model-C	100	50	200	50	400
Total	2000	3000	4000	1000	10000

Further, the above MPS can also contain information on sub models of a model, e.g.,

in a given week how many Model-1 will be produced with power steering and how many with power windows and so on.

Inventory Records File- Inventory record file contains the status of all the items in the inventory; it includes scheduled receipts of units of item in that interval of time as a result of orders placed in the recent past to suppliers. This necessarily contains 1) details of the suppliers of the items, 2) time taken by him to supply the item and 3) size of each order to be placed to him.

Inventory records file under a computerized system can be quite lengthy. Each item in inventory is carried as a separate file and the range of details carried about an item is almost limitless. The MRP program accesses the status segment of the file according to specific time periods. These files are accessed as needed during the program run.

Working of MRP program:

- A list of end items needed by time periods is specified by the master production schedule.
- A description of the materials and parts needed to make each item is specified in the bill of materials file.
- The number of units of each item and material currently on hand and on order are contained in the inventory file
- The MRP program "works "on the inventory file in addition, it continuously refers to the bill of materials file to compute quantities of each item needed.
- The number of units of each item required is then corrected for on hand amounts, and the net requirement is "offset" to allow for the lead time needed to obtain the material.

Outputs in materials requirement planning

MRP programme generates different reports as the output which is very important for the production managers for taking different decisions. The various outputs of MRP programme have been summarized as hereunder:

(1) ***Primary Reports*** **-** Primary reports are the main or normal reports used for the inventory and production control. These report consist of

(a) Planned orders to be released at a future time;

(b) Order release notices to execute the planned orders;

(c) Changes in due dates of open orders due to rescheduling;

(d) Cancellations or suspensions of open orders due to cancellation or suspension of orders on the master production schedule;

(e) Inventory status data.

(2) ***Secondary Reports*** - Additional reports, which are optional under the MRP system, fall into three main categories:

(a) **Planned Order Report-** Planned order report tells us about the planned orders that would be released in future date or during a given interval of time. This report helps in preparing the funds required for payments to the suppliers in the future according to the dates and order sizes.

For instance, April is the current month and the finance manager wants to see what quantities of raw material have to be made available in the month of May. This report helps him very much in preparing report that what amount of fund is required in May for making payments to the suppliers.

(b) **Order Release Report-** Order release report is that which gives information about planned orders which would be released on the present date .IT helps the purchase managers to release purchase orders purchase orders to the suppliers.

This report helps the purchase manager to keep track of the purchase order that have to be sent on a particular day. The material requirement planning logic makers use of the lead time of items in determining the release date of orders, so that goods are supplied by the time the items are required for production.

(c) **Order Changes Report-** These refer to the orders which have been placed in the past and the supplier of these items is preparing for these supplies to be made to the company. During the lead time the material requirement planning may fluctuate because some customers cancel their orders leading to revision of the mps because of this change in demand open orders have to revise.

In this case: Suppliers are told either to cancel the order s placed earlier by the company or to postpone them for some time or to reduce the order size to suit the current requirement. The order change report provides information to purchase

manager about all such changes to be made in the open orders with the suppliers.

Calculation of Order Size in MRP

There are 4 methods of calculating the order size in MRP

- Lot for lot method
- Economic Order Quantity (EOQ) method
- Least total cost method
- Least unit cost method

Let us take an example to understand all these methods. For an item the following information is given:

Ordering cost (OC) = Rs 50 per order

Carrying cost (CC) per unit per week = 0 .5% of unit cost

price Unit cost price = Rs 20

CC per week =20 X .5% =Rs 0.1

Week	Net requirement
1	80
2	100
3	90
4	60
5	110
6	50
Total	490

Let us calculate order size using four methods as follows

Lot for Lot Method:

In this the order size or the lot size is the same as the requirements at a point of time. In the above example, at the beginning of every week the planned order receipts (order size) exactly match the requirements of the item in that week. As shown in the excel sheet 1 below, the ending inventory as well as the CC of inventory is zero .There is no accumulation of inventory at any point of time, every week an order is placed, leading to an OC of Rs 50. The total cost is Rs 300 for this method.

Given that				ANNUAL DEMAN	D 4248.67	
ORDER COST =RS 50 PER ORDER				ANNUAL CARRYING COST =5.2/WEEK		

Carrying cost per week					(EOQ)2 = 81666.667		
UNIT COST PRICE= RS 20					EOQ =285.7738		
Carrying cost per unit per week = 20x0.5% =rs 0.1							
WEEK	Net requirement		lotsize	ending inventor	carrying cost	order cost	total cost
1	80		80	0	0	50	50
2	100		100	0	0	50	50
3	90		90	0	0	50	50
4	60		60	0	0	50	50
5	110		110	0	0	50	50
6	50		50	0	0	50	50
total	490				grand total		490
				LOT FOR LOT METHOD			
WEEK	Net requirement		lotsize	ending inventor	carrying cost	order cost	total cost
1	80		286	206	20.6	50	70.6
2	100		0	106	10.6	0	10.6
3	90		0	16	1.6	0	1.6
4	60		288	242	24.2	50	74.2
5	110		0	0	13.2	0	13.2
6	50		0	0	8.2	0	8.2
						grand tota	178.4
				EOQ METHOD			

Excel Sheet 1

Factory Layout Revision

The layout of factories can be revised to introduce assembly lines and manufacturing cells .sometimes called continuous flow manufacturing, the purpose of these layout modifications is to minimize material handling activities and their associated transactions and to provide faster quality feedback .Assembly lines are typically dedicated to a particular product type, although they may be able to produce multiple models. Manufacturing cells produce a variety of completed parts and the cells are developed using group technology .often in order to have the capability to handle certain surges in demand, excess capacity is built into the system.

Set-up Time Reduction

Factories can reduce set up times in order to reduce lot sizes and smooth production. Reduced set up times enables a factory to produce smaller lot sizes economically. Smaller lot sizes enable a factory to produce a broader variety of products, assemblies and parts each day .However, preventive maintenance and lowering defects rates are also needed to achieve these lower safety stock sizes.

Pull System Implementation

In a pull system, final assembly lines only produce actual orders and kanban cards are used to signal sub assembly and part deliveries, and production.MRP may be used and smooth production facilitates the use of a pull system.

Better coordination with suppliers

Factories can work with suppliers to reduce raw material inventories and solve quality problems. The first three techniques are applicable to the suppliers as well, for improving the material flow between a firm and its supplier's. The goal is to make the supplier an extension of the internal material flows, to avoid the problems associated with shifting of inventories from customers to suppliers.

Just- in-Time Manufacturing System

According to Schonberger, "Just-in-Time (JIT) is a system to produce and deliver finished goods just in time to be sold, sub assemblies just-in-time to be assembled into finished goods, and purchase materials just in time to be transformed into fabricated parts."

The idea of just in time was originally developed by the Toyota motor company in Japan .The idea was formalized into a management system when Toyota sought to meet the precise demand of customers for different models and colors of cars with minimum delays. JIT is being used in wide variety of industries such as automobiles, consumer electronics, office equipments etc.

JIT may be understood as the continuous improvement of material flow in either factory or a combination of factories.

There are four techniques in JIT for improving material flow which are as follows

- Factory layout revision
- Set up time reduction
- Pull system implementation
- Better coordination with suppliers

Kanban Visual Systems

Kanban is a Japanese word that means flag or signal, and is a visual aid to convey the message that action is required. The kanban inventory control system was originally introduced by the Toyota motor company in Japan. On a visit to the USA, Toyota's Vice President Taiichi Ohno noticed the technique, adapted by American

supermarkets for replenishing empty shelves in racks .Whenever a shelf was found drained of a product, it triggered the replenishment of the product to the shelf. It was so simple because an empty shelf was easily visible among the other shelves full of products. Ohno thought of implementing the same idea for replenishment at his assembly lines. He adapted this simple but effective method by using a trigger or kanban, to alert the manufacturing area that the assembly area was running low on components. Every component must have its own kanban to signal when it needs to be replenished.

The kanban system can be explained in the following stages:

Stage 1

When a worker needs components, he goes to the racks placed opposite his workstation. These racks contain bins of components required by a workstation, which from the work in process inventory. Every bin has the requisition kanban card affixed on it, which is removable .This card contains the component name, its identification number, and the rack number and shelf on the rack in the store where more bins of the component are stored.

The workers from the assembly line remove the kanban card from the bin, hang it on a hook on the rack, and take away the bin to their workstation for using the components in assembly operations. These hanging kanban cards are thus clearly visible from everywhere, signaling replenishment of components from the store.

Stage 2

A supply worker called "*Mizosomashi"* in Japanese keeps on moving in the aisle or the passage way across the racks his trolley. When he reaches the racks opposite the assembly line, he removes all the hanging requisition kanban cards and the empty bins from the racks. He then takes these along with him through the aisle to the racks in the store opposite the manufacturing cells.

Stage 3

Mizosomashi looks at the information on each requisition kanban card and locates the position of the rack and the shelf on the rack containing the bins full of a particular component .Every bin in the store has the production kanban card affixed on it, which is

removable. The production kanban card contains the name and identification number of the component to be manufactured in the cell. Mizosomashi takes off the bins from the racks corresponding to the requisition kanban card he had bought with him, and removes the production kanban card from these. He hangs these on the hooks on the corresponding racks in the store, attaches the requisition kanban cards on the bins, and puts the bins in the trolley to the racks opposite the assembly line and places the bins in the appropriate racks. Thus, the replenishment of the bins at the assembly line has taken place. Mizosomashi repeats this process at regular intervals of time.

Stage 4

One worker from each of the manufacturing cells goes to the rack placed opposite his cell with his trolley. He removes the hanging production kanban cards and places the empty bins from the rack in his trolley. He takes these to his manufacturing cell, where the different components mentioned on the production kanban cards are manufactured in exact quantities so as to fill the empty bins completely. The filled in bins with the production kanban cards attached to them are then taken from the manufacturing cell to the rack opposite the cell and placed on the appropriate shelf mentioned in the production kanban card.

JIT is a pull system, as opposed to the western norm of making bulk components and storing them just in case they are needed. The obvious benefits of using the kanban system are reduced inventory and less storage space required; however, the hidden benefit is the high quality of components. Production of components in small batches makes it easier to immediately detect defects in them. Thus reduced inventory acts as a buffer against bad quality.

Benefits of MRP System

MRP system is of immense importance in manufacturing organizations. The key benefits have been summarized as below:

- Reduced inventories without reduced customer service
- Ability to track material requirements
- Ability to evaluate capacity requirements
- Means of allocating production time

- Increased customer satisfaction due to meeting delivery schedules
- Faster response to market changes
- Improved labor and equipment utilization
- Better inventory planning and scheduling

In addition to above, the key outputs of MRP system are very helpful in:

- Calculating demand for component items
- Determining requirements for subassemblies, components, and raw material
- Determining when they are needed
- Generating work orders and purchase order
- Considering lead time

Summary

Material requirement planning is a system for determining order quantities and the time intervals for placing orders of dependent demand items e.f. components and raw materials etc. It requires three inputs, namely, master production schedule, bill of materials and inventory status. It generates three output reports – planned order reports, order release report, and order change report. Just in time is a manufacturing system in which work in process inventories are reduced to minimum levels. Small quantities of materials are supplied by the suppliers to the assembly line directly with the aid of visual kanban cards. In MRP, order size can be determined using four techniques namely, 1) Lot for lot method, 2) Economic Order Quantity (EOQ) method, 3) Least total cost method and 4) Least unit cost method.

MRP and JIT can be used together simultaneously as a hybrid MRP –JIT system, where MRP is used for planning materials requirement only, and the purchase orders sent to the suppliers act only as an indication of the probable requirements of the buyer company. The supplier supplies the goods only according to the JIT system of kanban cards.

Keywords

Bill of materials: is a document which tells us about the structure of a product, showing the sequence in which components sub assemblies are assembled and their required numbers. It also contains details about the workstations at which the item is

assembled.

Just in time system: is defined as produce and deliver finished goods just in time to be sold, subassemblies just in time to be assembled into finished goods and purchased materials just in time to be transformed into fabricated parts.

Kanban**:** is a Japanese word meaning flag or signal, and is a visual aid to convey the message that action is required.

Master production schedule*:* is an extension of the aggregate production plan. It tells us the number of units of different models of a product to be manufactured on a weekly or monthly basis in the coming 6-18 months.

Material requirement planning**:** is a system for planning the future requirements of dependent demand items.

Product structure: shows a product build up. It shows diagrammatically the components required to assemble it, their numbers, and the sequence of assembly.

Purchasing: refers to the actual buying materials and the activities associated with it.

Self assessment questions

1. What is materials requirement planning? What are the inputs and outputs required by the MRP processing logic?
2. What is product structure?
3. What is a bill of materials?
4. Give the general format of an MRP report using a hypothetical example.
5. Explain the various methods of determining the order size in MRP.
6. Define the Just in time system and explain the basic concept of JIT manufacturing?
7. What is kanban visual system? Explain the various steps followed in operating the kanban system in a plant.

INVENTORY MANAGEMENT;

Introduction:

Inventory is basically working capital and that is why control of inventories is very important as part of operations management. Inventories are crucial for proper functioning of manufacturing and retailing organizations. There are many types of inventories like raw

material, spare parts or consumables, work-in-progress and finished goods. It is not necessary that every organization needs these resources but should work according to the needs and requirements of the resources depending upon what type of production is taking place.

Various departments within the same organization have a contradictory approach towards these kinds of resources. This is because the functions that are performed in various departments influence the motivation in them. For example, the sales department might need large amount of stocks of materials so that the production systems run very smoothly with any hesitation. On the other hand, the finance department would need a minimum investment in stocks so that the funds could be used elsewhere for even better purposes to enhance the performance of the organization.
There are different inventory systems that determine the when to order and how much to order. In this chapter, we will discuss all of them in detail.

Types of Inventory:

Inventories are used for many different purposes and by various departments for their respective needs and requirements, but there are generally five types of inventories that every production organization should emphasis on:

1) Movement inventories
2) Buffer inventories
3) Anticipation inventories
4) Decoupling inventories
5) Cycle inventories

1) Movement Inventories:

Everyday resources are being transported to the industries and putting them to use by production organization through various modes of transportation. Movement inventories are also called transit or pipeline inventories. This is basically dealt with transporting the resources from source to destination. For example, coal is transported from coalfields to an industrial township by trains, then the coal, while being transported will not be able to

provide any service to the customers for power generation or for burning furnaces etc.

2) Buffer Inventories:

These inventories are basically kept for future needs for the organization in stock because there may a case when more inventories would be needed and therefore every organization keeps an average amount of inventories in stock so that the organization can utilize those resources efficiently and effectively without any delay. This mainly calls for uncertainty in demand, as every organization would need the required amount of stock but what would happen when the stock runs out? Everything would stop mainly the production so it is very important that excess amount of resources should be kept in stock. Similarly, the average time for delivery that is (the time between placing the order of resources and receiving those orders and getting them ready for use in stock, technically known as lead-time).

The idea of keeping buffer stocks is to enhance the level of providing customer service and gradually reducing the number of stock outs and back-orders. Stock out is something when the stock runs out and the needs of customers are not being able to fulfilled but in some situations back ordering is possible that is (the order for goods demanded is fulfilled as soon as the next shipment of stock arrives.) while in others it is not as it looks because the demand might be lost forever which leads to temporary or permanent loss of customer goodwill.
So it is very important to keep buffer stocks as demand may arise at any point of time.

3) Anticipation Inventories:

Anticipation inventories are put under scrutiny for future demands so that when the time arrives, the supply of products flow rapidly. Like producing rain coats before the rainy season, creating crackers before Diwali etc. The idea under this is to smoothen the flow of production process for longer time on an iterative scale instead of operating with excess overtime in a particular period and then keeping the system idle for long or even shut down the system because of unnecessary demand for another period.

4) Decoupling Inventories:

This type of inventory deals with the work rate of different machines and people because

normally machines work at different rates- some slower and some faster. For example, a machine might be producing half the output of the machine on which the item being handled is to be processed the next. Inventories in between the various machines are held in order to disengage the processing on those machines. In absence of those inventories, different machines and people cannot work on a continuous basis. Clearly, therefore the decoupling inventories act as shock absorbers and have a cushioning effect in the face of varying work rates, and machine breakdowns and failures and so on.

5) Cycle Inventories:

Cycle inventories are those when purchases in lots instead in exact amount of stock need in a specific point of time. But yes if all purchases are made as per the exact requirement of stock there would have been no cycle inventories. But then the cost in getting these stocks would be much higher as per the customer needs and requirements. They are also called lot-size inventories and larger the lot-size inventory the greater would be the level of cycle inventory.

Inventory Decisions:

It is very important and is the top most priority of deciding about the inventories in a production organization as this would decide the future and present performance of the company. In any production organization deciding the inventories according the needs and requirements of it is very important. This can enhance the performance or bring down the efficiency.

So there are specific things any production manager should keep in mind before making decisions. They are:

- How much to order? – This is decided by the manager as to how much quantity to order for optimal performance and effective utilization of resources.
- When to order? – This is the most important aspect the manager should emphasize on because this would decide when should the products be ordered.
- How much stock should be kept in safety? – This indicates how much quantity should be taken under consideration so that the stock can be used safely in the future without any hesitation.

Inventory Costs:

For deciding the best suitable inventory policy, the top most criteria used is the cost function. This inventory analysis has four major components:

1) Purchase Cost:

This is basically the nominal cost of an inventory. It is the cost incurred in buying from the outside sources, and it would be known as production cost if the items are produced within the organization. The cost is constant for a unit but may vary according to the quantity purchased increases or decreases. For example, the unit price is Rs.20 for up to 100 units and Rs.19.50 for more than 100 units. If a unit cost is constant, the control decisions would not have any affect because whether all the requirements are produced just once or made in installments the total amount of money involved would be the same.

2) Ordering Cost/Set-up Cost:

This occurs whenever the stock replenishes. It associates with the processing and chasing the purchased order, transportation, and inspection for quality. It is also called procurement cost. The parallel of ordering cost when the units are produced within the organization is the set-up cost. It refers to cost incurred in relation to developing production schedules. The ordering cost and set-up cost are taken to be independent to the order size. So the unit ordering/set-up cost decreases as the purchase order increases.

3) Carrying Cost:

Carrying cost is also known as holding cost and it refers to the cost that is associated with storing an item in the inventory. It is proportional to the amount of inventory and the time taken to hold that inventory. The elements of carrying cost include opportunity cost, obsolescence cost, deterioration cost. The carrying cost is expressed in terms of rate per unit or as a percentage of the inventory value.

4) Stockout Cost:

Stock out cost is the cost, which incurs when customers are not being served. These costs imply shortages. If stock out is internal, that means that some production is lost internally also resulting in idle time for man and machines. If stock out were external, it would result in potential sales or loss of customer goodwill. When the new shipment arrives, a customer who was denied earlier would be immediately supplied the goods. But it would

involve costs like packaging costs and shipment costs.

Inventory Management Systems:

There are basically two types of management systems:

- ***Fixed order quantity system:*** Also known as re-order point, when a specific level is reached called the re-order level and the stock level reached this point, an order for a particular number of units is placed;
- ***Periodic Review System:*** This is a system where the stock is replenished over a fixed period of time. In this system, the time after which the order is placed, is fixed, but not the quantity.

Fixed Order Quantity System:

This system also called the Q-System. In this, a re-order point is established and as soon as the stock level reaches this level, new set of orders are placed. This system is taken under consideration of certainty. A couple of models based on different conditions shall be developed to study various operations of the system under deterministic conditions.

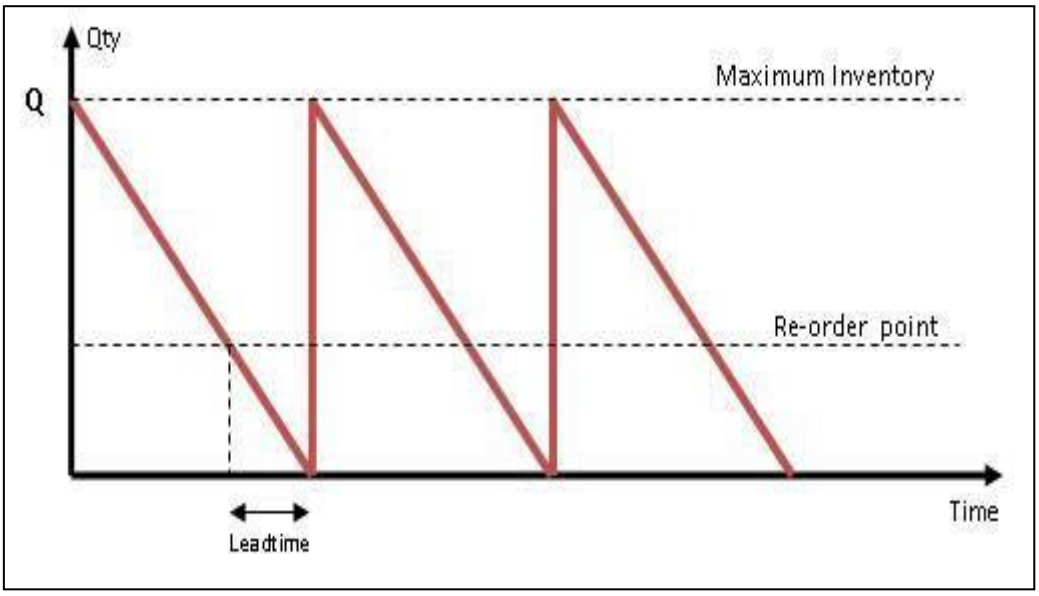
Model 1: The Classical EOQ Model

EOQ stands for Economic Order Quantity also known as the Wilson Formulation. It is the most elementary of all the inventory models. For this, a fixed cost model is made and then it is manipulated to form an inventory model.

This model is based on the following assumptions:

1) The demand for the item is continuous, constant and certain over time.
2) The purchase price is constant, and no discount is available on the large lots.
3) The inventory is replenished immediately as the stock level reaches level equal to zero. So there is no shortage or overage.
4) The lead is always known and fixed. When the lead-time is zero, the delivery of item is instantaneous.
5) Within the range of quantities ordered, per unit holding cost and the ordering cost are constant and thus independent of the quantity ordered.

With these assumptions, the inventory level would vary over time as shown in the graph 1 as below:



Graph 1

Now, we begin with a stock of Q on the time zero. This will be consumed at the rate of some units per day. If the stock can be replenished instantaneously (that means lead time is zero), then a new set of orders is made and the inventory is obtained. When this stock is consumed, an order would be made at another time.

The interval between two different points when orders are placed, or the time elapsed in consuming the entire lot of items, is called the inventory cycle. The maximum inventory held would be Q while the minimum be zero, and hence the average inventory level would be equal.

There is no need for maintaining a safety stock because of the first two assumptions. For determining the optimum order quantity, we shall take two types of cost: ordering cost and the holding cost. Since the purchase price is uniform in nature, it does not affect the decision as to the quantity of the item to be ordered for purchase and, hence, is irrelevant for the purpose.

Economic Manufacturing Batch Size:

The EOQ concept can be further extended to the determination of optimal manufacturing batch size for semi-finished and finished goods. If the batch size is large, then the average level of inventory is also large therefore the carrying costs for the inventory are high. But a few cases like, large batches of would suffice for the annual requirements, the number of set-ups would be low. On the other hand, when batch size is small, the order cost is higher,

but at the same time, the average inventory level is smaller thus making the carrying cost lower. Thus, there is clear trade-off between costs involved.

Cost of Setup:

The set-up cost mainly includes the following:

1) Cost of time spent in setting up the equipments and organizing the labour for a manufacturing batch. This is the cost of the idle time of labour and the machinery, which would have otherwise produced goods. This is the opportunity cost of the time lost due to a set-up.
2) Cost due to rejects, scrap, rework generated during a set-up.
3) Variable cost of administrative paper work for a set-up.

Calculation of Economic Batch Quantity:

The Economic Batch Quantity (EBQ) Formula for a single product is:

This expression is similar to that derived for the classical inventory model except for the fact that it takes into consideration production and consumption rates of the product.

Safety Stock

The inventory models discussed so far are based on the common assumption of constant and know demand for the item and the lead-time. Therefore, these models are called deterministic models. The models that consider the situation in which the demand and demand and/or lead-time are not known with certainty and they need not be constant is beyond the scope of this chapter. In these models, demand and lead time are taken as random variables, capable of assuming varying values whose probability distribution may be known.

In the models, the stock is replenished as soon as the stock reaches the point of exhaustion, due to the assumption underlying them. Under such idealistic situation, there is no need to maintain any extra stock because the supplies would reach the moments the stock level reduce to zero and there would be no stock outs (unless they are intentionally allowed to occur). However when the demand is varying and so is the lead time, there is a need to

provide for the safety or buffer stock in order to meet either or both the lead time, there is a need to provide for the safety or buffer stocks in order to meet either or both the contingencies, viz. that demand rate during the lead time is in excess of what was expected/forecasted and that the delivery of good is delayed. The safety stock, then acts as a cushion against stock-outs caused by random deviations of nature.

The safety stock is an important constituent of the re-order level that is determined as the expected demand of the item during lead time plus the safety stock. If the demand varies about the mean daily demand equal to d with the expected lead time equal to L days, and we set the re-order level R at L units, then we should expected a shortage to occur in about half the lead time periods. To reduces this 50% probability of being out of stock, the safety stock SS would be required to be kept. Thus,
Re-order level, R = L* d +S.S.

We know that in this system, an order is placed as soon as it reaches the re-order level. Therefore, how high or low is the rate of demand before the re-order level reaches is of little consequence. What is significant is the level of demand during the lead-time. Here fresh supplies are received as soon as the stock level reaches the safety level. In this kind of a situation, the average stock held would be exactly equal to SS + Q/2.

The idea of keeping the safety stock is clearly to prevent stock out and it is the amount of stock that the organization would always like preserve for meeting extraordinary situation. In general higher safety stock would be called for in situation where costs of stock out are larger; higher levels of service (i.e. meeting greater proportion of demand) are sought; significant variation are observed in the lead time and/or time demand; and where holdings costs are smaller. Naturally, the higher the level of safety stock the greater the service level and therefore to strike a balance between the two, The optimal safety stock level is determined where successively declining stock out costs and successively rising holding costs, caused by the successive units added to the safety stock, would balance.

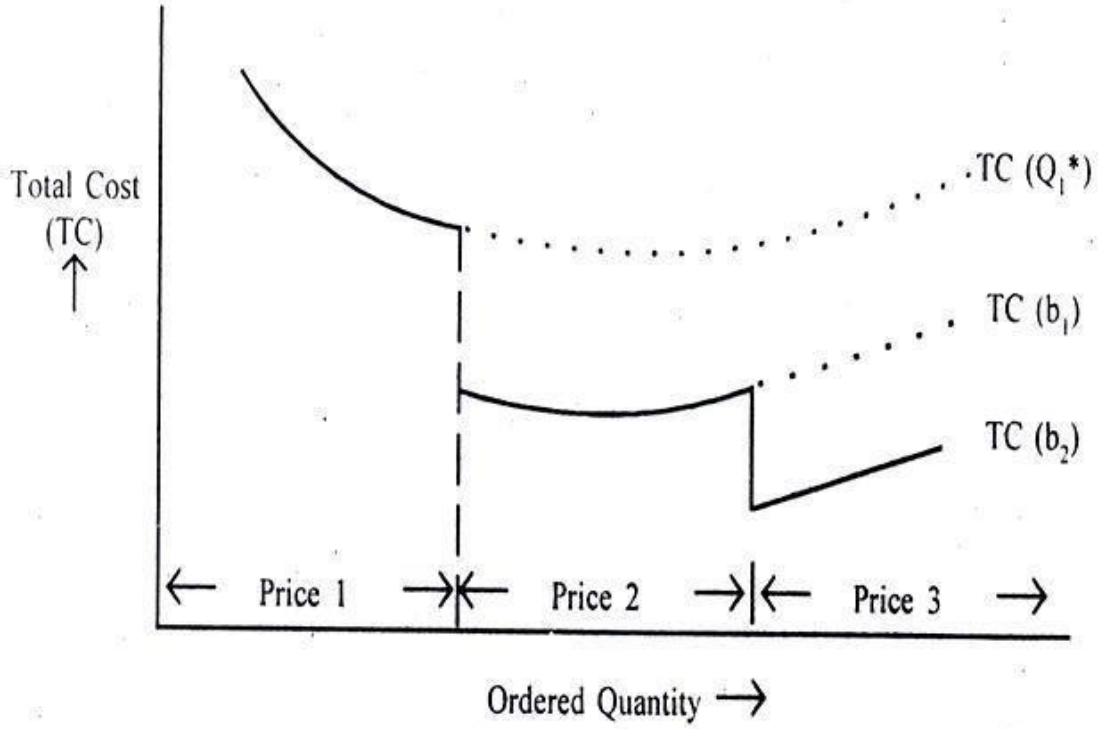
There is no rigid formulation for determining the optimum level of safety. The different approaches available for the purpose are based on the demand, the lead time and the stock out costs. The complexity of the situation is determined by the extent and nature is determined by the extent and nature of information available about these factors.

Inventory Model with Purchase Discounts:

The classical model for inventory does not take into account, amongst other things, the quantity discounts given by the supplier if material is purchased in bulk. As the discount might be relevant in the inventory analysis, this could be included in the total relevant cost and therefore in this case, the total cost function becomes:

Where is the supply price per unit of the inventory item and f is the carrying cost of the inventory expressed as a fraction of the inventory value.(Other nomenclature remains the same.)

Differentiating the total costs with respect to Q and equating the result to zero, we get the optimal procurement quantity.



At the two different prices (1 and 2) the $Q_{optimal}$ values are different. Which one shall we choose $Q_{optimal}$ for price 1 or $Q_{optimal}$ for price 2 the answer is not straightforward. We shall have to plot the total cost (relevant) with respect to the procurement lost size. For lot sizes less than b price 1 is operative and we get a total cost curve corresponding to it. For lot sizes equal to or greater than b we get another total cost curve. These curves need not exhibit minima within their zone. Price 1 total cost curve can have a minimum in the zone where price 2 is operating. Conversely. Price 2 total cost curve can have a minimum in zone where price 1 is operating.

It should be noted that due to the earlier given equations, the total cost curve for the

second price will always be lower than the total cost curve for the first price, the minimum total cost for the second price will be lower than the minimum total cost for price 1, and the $Q_{optimal}$ for price 2 will always be higher than $Q_{optimal}$ for price 1. In spite of this, the three possibilities arise.

Here again, it is obvious that we choose $Q_{optimal}$ in fact $Q_{optimal}$ does not exit. The lowest of the total cost at price 1 is at price 1 is lot size 'b' and this total cost will have to be higher than the total cost for $Q_{optimal.}$

Here price 2 curve shows a minimum in the price 1 zone and the minimum is therefore imaginary. Hence, the only choice is between $Q_{optimal}$ and the price break quantity (at which the real part of the price 2 curve begins). This can be decided by comparing the total costs corresponding to the two choices.

The determination of the optimal quantity in the case of purchase discounts, therefore, follows the procedure given below:

1. Calculate $Q_{optimal}$ the optimal lost size corresponding to price 2.
2. Find out if the $Q_{optimal}$ falls in its own range. If so, desired optimal order quantity is $Q_{optimal}$ if not, carry out the following procedure.
3. Compare the total cost at $Q_{optimal}$ with the total cost corresponding to the lost size b' (price break quantity) at the second price. If the former is less than the latter,

Choose $Q_{optimal}$ Otherwise, the optimal order quantity is equal to the price-break point.

Example: The supply of a special component has the following price schedule.

0 to 99 item: Rs 1000 per unit

100 items and above: Rs 950 per unit

The inventory holding costs are estimated to be 25% of the value of the inventory. The procurement ordering costs are estimated to be Rs. 2,000 per order. If the annual requirement of the special component is 300, compute the economic order for the procurement of these items.

Steps 2 and 3:

Therefore, we have to determine the optimal total cost for the first price and total cost at the price-break point corresponding to the second price, and compare the two.

The total cost (optimal for the first price)

$$=\sqrt{2 \square 2000 \square 1000 \square 0.25 \square 300} + 1000 \square 300$$

=17,320+300,000=Rs.3,17,320

The total cost for the price-break point (corresponding to the second price):

$$TC=200 \times \frac{300}{100} + \frac{100}{2} \times 950 \times 0.25 + 950 \times 300$$

=6,000 + 11,875 + 285,000

=3,02,875

This is lower than the total cost corresponding to $Q_{optimal.}$

Therefore, the economic quantity for a procurement lot is 100 units (price-break point).

Consideration of Uncertainties:

In the above given models for the determination of 'normal' inventory consumption rates were assumed to be constant. In actual practice, there are always uncertainties stemming from two basic reasons:

1. Variability in sales, hence variability in the demand for the materials or the consumption of the materials
2. Delay in the supplies of raw materials.

Summary:

- Inventory serves a useful purpose in the manufacturing organizations. Firms can help minimize the need for inventory by carefully managing those factors that drive inventory levels up
- Inventory items can be divided into two main types: Independent demand and dependent demand items. The systems for managing these two types of demand, inventories differ significantly
- The two classic systems for managing independent demand inventory are periodic review and perpetual review systems
- The economic order quantity (EOQ) is the order quantity that minimizes total holding and ordering costs for the year. Even if all the assumptions don't hold exactly, the EOQ gives us a good indication of whether or not current order quantities are reasonable

- The reorder point formula allows us to determine the safety stock (SS) needed to achieve a certain cycle service level. In general, the longer the lead times are, and the greater the variability of demand and lead times, the more SS we will need
- Inventories are vital to the successful functioning of manufacturing and retailing organizations
- The basic questions to keep in mind before getting any inventory:
    a) How much inventory to keep
    b) When to keep the inventory in the warehouse
- Buffer stock is kept for review period + lead-time
- Maximum inventory on hand is (Normal consumption + Buffer Stock) both for review period plus on order.

Keywords:

- ***Inventory:*** is working capital and therefore the control of inventories is an important aspect of operations management
- ***Lead Time:*** The time elapsing between placing an order and having goods in stock
- ***Procurement costs:*** associated with processing and chasing of an order, transportation, inspection for quality, expediting overdue orders and so on

Self-assessment Questions:

1. Define inventory. Discuss various types of inventory costs.
2. Discuss various types of inventories.
3. What are the basic assumptions underlying the classical EOQ model? Also discuss its limitations.
4. What is the set-up cost of manufacture?
5. Discuss economic batch quantity with suitable example.

UNIT III
SCHEDULING

INTRODUCTION

Aggregate Planning is an intermediate planning method used to determine the necessary resource capacity a firm will need in order to meet its expected demand. It is an intermediate range capacity planning, usually covering 2/3 to 12/18 months. In other words, it is the matching of capacity and the demand in such a way that cost are minimized.

Definition

The term Aggregate Planning is defined as, "An operational activity which does an aggregate plan for the production process, in advance of 2 to 18 month, to give an idea to management as to what quantity of materials and other resources are to be procured and when, so that the total cost of operations of the organization is kept at minimum over that period".

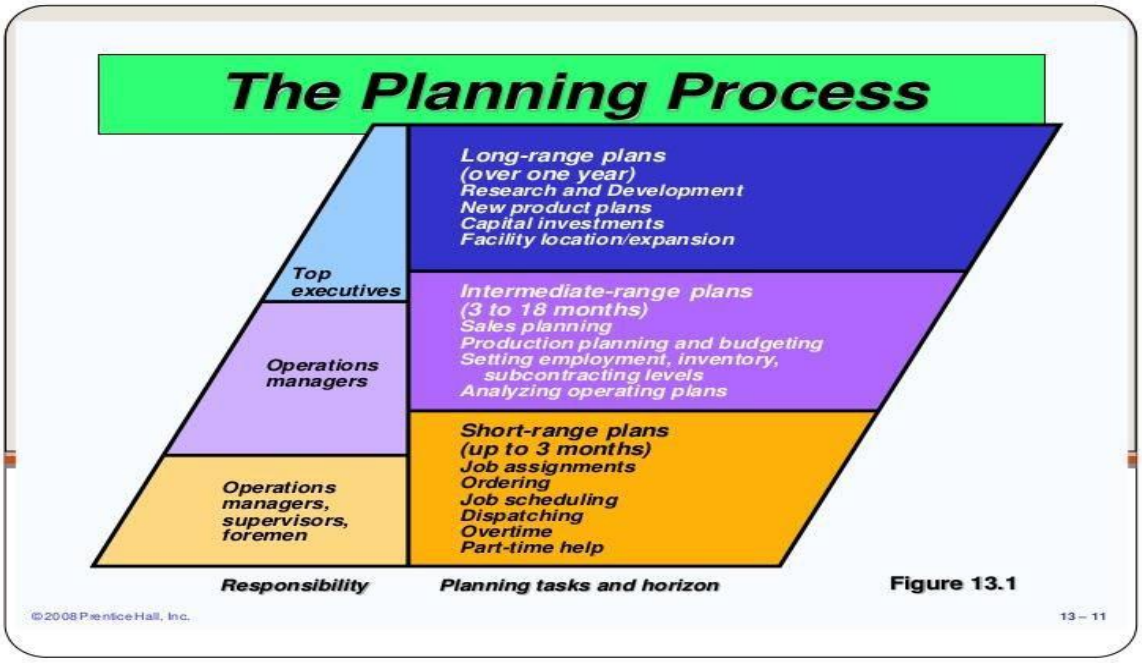
Aggregate planning is the process of developing, analyzing, and maintaining a preliminary, approximate schedule of the overall operations of an organization. The aggregate plan generally contains targeted sales forecasts, production levels, inventory levels, and customer backlogs. This schedule is intended to satisfy the demand forecast at a minimum cost. Properly done, aggregate planning should minimize the effects of shortsighted, day-to-day scheduling, in which small amounts of material may be ordered one week, with an accompanying layoff of workers, followed by ordering larger amounts and rehiring workers the next week. This longer-term perspective on resource use can help minimize short-term requirements changes with a resulting cost savings.

The main objectives of aggregate planning are summarized as hereunder:

- Maximize customer service.
- Minimize inventory investment.
- Minimize changes in workforce levels.
- Minimize changes in production rates.
- Maximize utilization of plant and equipment.

In simple terms, aggregate planning is an attempt to balance capacity and demand in such a way that costs are minimized. The term "aggregate" is used because planning at this level includes all resources "in the aggregate;" for example, as a product line or family.

Aggregate resources could be total number of workers, hours of machine time, or tons of raw materials. Aggregate units of output could include gallons, feet, pounds of output, as well as aggregate units appearing in service industries such as hours of service delivered, number of patients seen, etc.



Aggregate planning does not distinguish among sizes, colors, features, and so forth. For example, with automobile manufacturing, aggregate planning would consider the total number of cars planned for not the individual models, colors, or options. When units of aggregation are difficult to determine (for example, when the variation in output is extreme) equivalent units are usually determined. These equivalent units could be based on value, cost, worker hours, or some similar measure.

Aggregate planning is considered to be intermediate-term (as opposed to long- or short-term) in nature. Hence, most aggregate plans cover a period of three to 18 months. Aggregate plans serve as a foundation for future short-range type planning, such as production scheduling, sequencing, and loading. The master production schedule (MPS) used in material requirements planning (MRP) has been described as the aggregate plan "disaggregated."

Steps taken to produce an aggregate plan begin with the determination of demand and the determination of current capacity. Capacity is expressed as total number of units per time period that can be produced (this requires that an average number of units be computed since the total may include a product mix utilizing distinctly different production times). Demand is expressed as total number of units needed. If the two are not in balance (equal),

the firm must decide whether to increase or decrease capacity to meet demand or increase or decrease demand to meet capacity. In order to accomplish this, a number of options are available.

Options for situations in which demand needs to be increased in order to match capacity include:

1. **Pricing.** Varying pricing to increase demand in periods when demand is less than peak. For example, matinee prices for movie theaters, off-season rates for hotels, weekend rates for telephone service, and pricing for items that experience seasonal demand.
2. **Promotion.** Advertising, direct marketing, and other forms of promotion are used to shift demand.
3. **Back ordering.** By postponing delivery on current orders demand is shifted to period when capacity is not fully utilized. This is really just a form of smoothing demand. Service industries are able to smooth demand by taking reservations or by making appointments in an attempt to avoid walk-in customers. Some refer to this as "partitioning" demand.
4. **New demand creation.** A new, but complementary demand is created for a product or service. When restaurant customers have to wait, they are frequently diverted into a complementary (but not complimentary) service, the bar. Other examples include the addition of video arcades within movie theaters, and the expansion of services at convenience stores.
5. Options which can be used to increase or decrease capacity to match current demand include:

    a) **Hire/lay off.** By hiring additional workers as needed or by laying off workers not currently required to meet demand, firms can maintain a balance between capacity and demand.
    b) **Overtime.** By asking or requiring workers to work extra hours a day or an extra day per week, firms can create a temporary increase in capacity without the added expense of hiring additional workers.
    c) **Part-time or casual labor.** By utilizing temporary workers or casual labor (workers who are considered permanent but only work when needed, on an on-call basis, and typically without the benefits given to full-time workers).
    d) **Inventory.** Finished-goods inventory can be built up in periods of slack demand and then used to fill demand during periods of high demand. In this way no new

workers have to be hired, no temporary or casual labor is needed, and no overtime is incurred.

e) **Subcontracting.** Frequently firms choose to allow another manufacturer or service provider to provide the product or service to the subcontracting firm's customers. By subcontracting work to an alternative source, additional capacity is temporarily obtained.

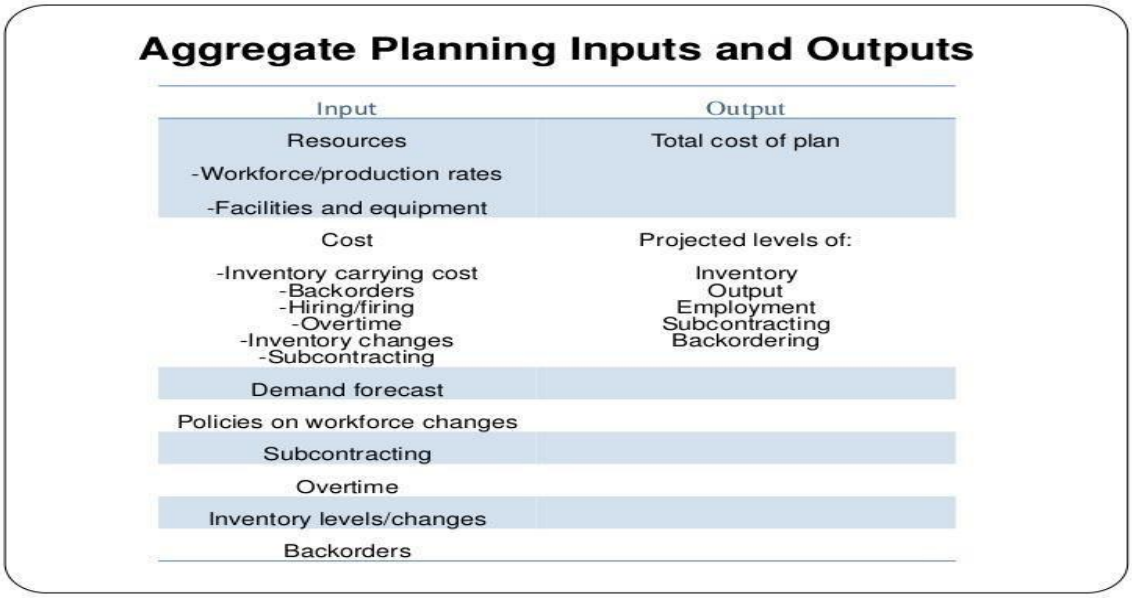
f) **Cross-training.** Cross-trained employees may be able to perform tasks in several operations, creating some flexibility when scheduling capacity.

g) **Other methods.** While varying workforce size and utilization, inventory buildup/backlogging, and subcontracting are well-known alternatives, there are other, more novel ways that find use in industry. Among these options are sharing employees with counter-cyclical companies and attempting to find interesting and meaningful projects for employees to do during slack times.

Aggregate Planning Inputs and Outputs:

In the figure as below, one can see all the necessary inputs required in aggregate planning. The important ones are including availability of resources, cost of equipments, cost of inventories etc.

The output generated mainly includes the total cost of plan and estimated levels of inventory, employment etc. These outputs are very significant in the decision making.



The main benefits are as follows:

- Determine demand for each period.
- Determine capacities for each period.
- Determine pertinent company policies.
- Determine unit cost based on all relevant sources.
- Develop alternative plans and calculate the cost for each.
- Choose the best overall plan based on company objectives and cost.

Aggregate Planning Strategies

There are two pure planning strategies available to the aggregate planner: a level strategy and a chase strategy. Firms may choose to utilize one of the pure strategies in isolation, or they may opt for a strategy that combines the two.

LEVEL STRATEGY

A level strategy seeks to produce an aggregate plan that maintains a steady production rate and/or a steady employment level. In order to satisfy changes in customer demand, the firm must raise or lower inventory levels in anticipation of increased or decreased levels of forecast demand. The firm maintains a level workforce and a steady rate of output when demand is somewhat low. This allows the firm to establish higher inventory levels than are currently needed. As demand increases, the firm is able to continue a steady production rate/steady employment level, while allowing the inventory surplus to absorb the increased demand.

A second alternative would be to use a backlog or backorder. A backorder is simply a promise to deliver the product at a later date when it is more readily available, usually when capacity begins to catch up with diminishing demand. In essence, the backorder is a device for moving demand from one period to another, preferably one in which demand is lower, thereby smoothing demand requirements over time.

A level strategy allows a firm to maintain a constant level of output and still meet demand. This is desirable from an employee relations standpoint. Negative results of the level strategy would include the cost of excess inventory, subcontracting or overtime costs, and

backorder costs, which typically are the cost of expediting orders and the loss of customer goodwill.

CHASE STRATEGY

A chase strategy implies matching demand and capacity period by period. This could result in a considerable amount of hiring, firing or laying off of employees; insecure and unhappy employees; increased inventory carrying costs; problems with labor unions; and erratic utilization of plant and equipment. It also implies a great deal of flexibility on the firm's part. The major advantage of a chase strategy is that it allows inventory to be held to the lowest level possible, and for some firms this is a considerable savings. Most firms embracing the just-in-time production concept utilize a chase strategy approach to aggregate planning.

Most firms find it advantageous to utilize a combination of the level and chase strategy. A combination strategy (sometimes called a hybrid or mixed strategy) can be found to better meet organizational goals and policies and achieve lower costs than either of the pure strategies used independently.

Techniques for Aggregate Planning

Techniques for aggregate planning range from informal trial-and-error approaches, which usually utilize simple tables or graphs, to more formalized and advanced mathematical techniques. William Stevenson's textbook *Production/Operations Management* contains an informal but useful trial-and-error process for aggregate planning presented in outline form. This general procedure consists of the following steps:

1. Determine demand for each period.
2. Determine capacity for each period. This capacity should match demand, which means it may require the inclusion of overtime or subcontracting.
3. Identify company, departmental, or union policies that are pertinent. For example, maintaining a certain safety stock level, maintaining a reasonably stable workforce, backorder policies, overtime policies, inventory level policies, and other less explicit rules such as the nature of employment with the individual industry, the possibility of a bad image, and the loss of goodwill.
4. Determine unit costs for units produced. These costs typically include the basic production costs (fixed and variable costs as well as direct and indirect labor costs).

Also included are the costs associated with making changes in capacity. Inventory holding costs must also be considered, as should storage, insurance, taxes, spoilage, and obsolescence costs. Finally, backorder costs must be computed. While difficult to measure, this generally includes expediting costs, loss of customer goodwill, and revenue loss from cancelled orders.

5. Develop alternative plans and compute the cost for each.
6. If satisfactory plans emerge, select the one that best satisfies objectives. Frequently, this is the plan with the least cost. Otherwise, return to step 5.

Passive (reactive) Strategies in Aggregate Planning:

There are mainly two types of approaches in aggregate planning that have been discussed as below:

Chase approach

The chase method helps the firms to match production and demand by hiring and firing workers as necessary to control output. The Capacities (workforce levels, production schedules, output rates, etc.) are adjusted to match demand requirements over the planning horizon.

Merits:

- Anticipation inventory is not required, and investment in inventory is low
- Labor utilization is kept high

Demerits:

- Expense of adjusting output rates and/or workforce levels
- Alienation of workforce

Level Approach

The Level method allows for a constant rate of production and uses inventory levels to absorb fluctuations in demand. The Capacities (workforce levels, production schedules, output rates, etc.) are kept constant over the planning horizon

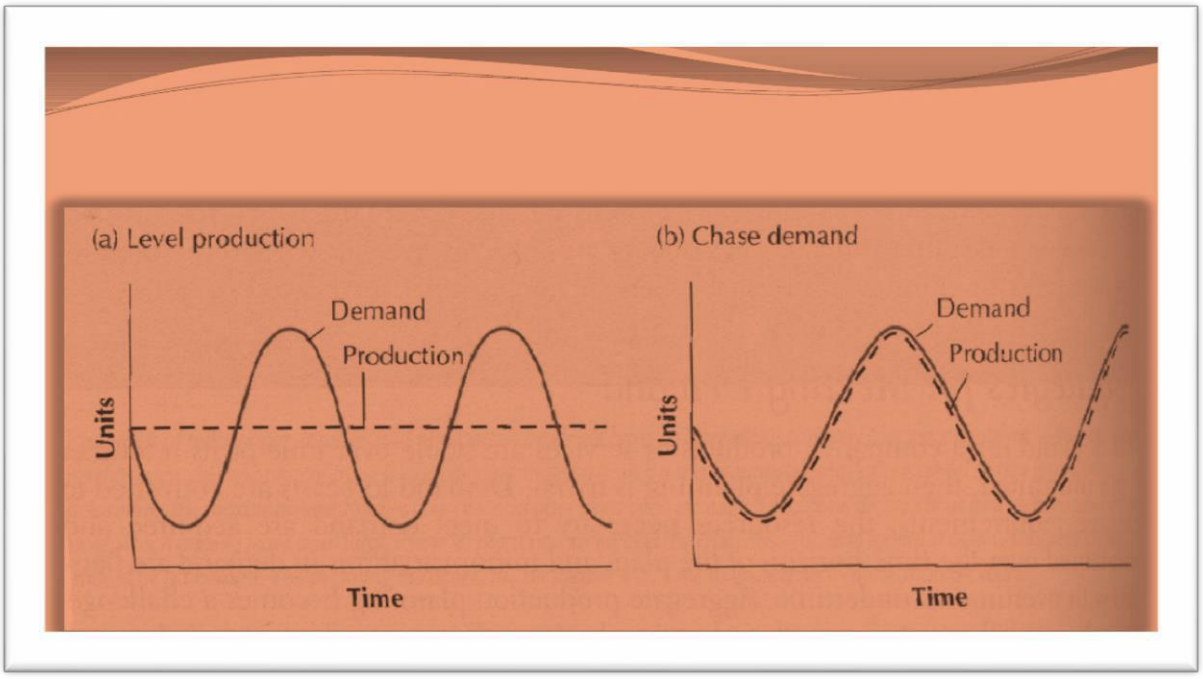
Merits:

- Stable output rates and workforce levels

Demerits:

- Greater inventory investment is required
- Increased overtime and idle time

- Resource utilizations vary over time



Aggregate Planning Methods/ Techniques

Techniques for aggregate planning range from informal trial-and-error approaches, which usually utilize simple tables or graphs, to more formalized and advanced mathematical techniques. Some Common Techniques are followings:

- Graphical/ Charting Method
- Linear Programming
- Simulation

Aggregate Planning Strategies

Active strategy:

- Attempts to handle fluctuations in demand by focusing on demand management
- Use pricing strategies and/or advertising and promotion
- Develop counter-cyclical products
- Request customers to backorder or advance-order
- Do not meet demand

Passive strategy (reactive strategy):

- Attempts to handle fluctuations in demand by focusing on supply and capacity

management

- Vary size work force size by hiring or layoffs
- Vary utilization of labor and equipment through overtime or idle time
- Build or draw from inventory
- Subcontract production
- Negotiate cooperative arrangements with other firms
- Allow backlogs, back orders, and/or stock outs

Mixed strategy:

- Combines elements of both an active strategy and a passive (reactive) strategy
- Firms will usually use some combination of the two

Aggregate Planning Methods: Intuitive Methods

Intuitive methods use management intuition, experience, and rules-of-thumb, frequently accompanied by graphical and/or spreadsheet analysis. Its main benefit is that it is easy to use. But it gives many solutions most of which are not optimal.

Aggregate Planning Example:

Suppose you have the following forecasts for demand to meet:

Month	1	2	3	4	5	6
Demand	1000	1200	1500	1900	1800	1600

Relevant Costs:

Regular production cost	$35/unit
Lost sales	$100/unit
Inventory carrying costs	$10/unit/month
Subcontracting costs	$60/unit
Hiring costs	$1500/worker
Firing costs	$3000/worker
Beginning workforce level	20 workers
Capacity per worker	50 units/month
Initial inventory level	700 units
Closing inventory level	100 units

LEVEL PRODUCTION STRATEGY

Find the requirements for the period of the plan and produce the average amount needed per month to meet the plan.

First determine the average requirements per month:

$$\text{Avg. requirements} = \frac{\text{total requirements - opening inv. + closing inv.}}{\text{Number of periods}}$$

Avg. requirements = (9000 - 700 + 100)/6 = 1400 units/period

Steps:

1. Enter the production data
2. Determine hire/fire to get to production level desired
3. Update inventory levels
4. Does the inventory run out - If it does recalculate average production needed and go to step 1
5. Calculate totals for each category
6. Calculate costs

LEVEL STRATEGY

Period	1	2	3	4	5	6	Total
Req.	1000	1200	1500	1900	1800	1600	9000
Prod.							
Inv.(700)							
Hire							
Fire							
Sub.							

Costs:

1. Regular production costs:
2. Inventory carrying costs:
3. Hiring Costs:

CHASE STRATEGY

- Produce exactly what is required every period.
- Hire and fire to adjust monthly production to monthly requirements.
- The first and last period production levels are adjusted to account for opening inventory and closing inventory requirements.

Period	1	2	3	4	5	6	Total
Req.	1000	1200	1500	1900	1800	1600	9000
Prod.							
Inv.(700)							
Hire							
Fire							
Sub.							

Costs:

1. Regular production costs:
2. Inventory carrying costs:
3. Hiring Costs:
4. Firing Costs:

TOTAL COSTS: _____

Limitations of Aggregate Planning

Planners use economic models and forecasting research to organize a firm's life to respond to the inevitable changes of the broader economy. Production planning does this in response to changes in demand. Changing a company's production schedule on a moments notice can be expensive and lead to insecurity and uncertainty. Planning for changes in demand months in advance ensures that the change of production schedules can occur with little effort. Aggregate production planning is a general approach to altering a company's production schedule to respond to forecasted changes in demand.

Resource Allocation

Aggregate production planning is really about the allocation of resources. Assuming that a plan is basically accurate, a production plan, usually stretching no more than a year into

the future, will ensure the smooth transition of production capacity as demand changes over time. The significance of this is that once employees are habituated to these changes, they will alter their own schedules and work habits to reflect changes in demand. This means that costs of changing work schedules will be minimized, increasing efficiency.

Overproduction Risk

This kind of planning reduces the risk of overproduction. During periods of demand slump, overproduction can waste resources, depress prices and over saturate the market. It might also tax the ability of a firm to store and maintain the productions that have been produced with nowhere to go. Aggregate production planning reduces production at times of weak demand. This means that money will be saved when production is curtailed, since the firm will not have to pay for labor that, because of weak demand, has no purpose.

Data and Bias

Like with all plans, they are only as good as the people who make them. Planners often have biases, prejudices and habituation that derive from their experience and education. These, if unchecked, can lead to a plan that misreads economic indicators or relies on faulty data like economic forecasting models. A production plan cannot take shocks into consideration, such as a spike in oil prices, Federal Reserve policies, interest rate hikes or changes in consumer confidence. As the name suggests, these plans can only deal with "aggregates" or averages that are only a partially successful tool to predict fluctuations in demand.

Labor and Uncertainty

Labor remains one of the most serious problems of aggregate production planning. For example, a company plans to increase overtime hours and hire part-time workers for peak demand seasons. It will then cut hours and give unpaid furloughs during poor demand seasons. This implies that workers, especially long-term ones, will become increasingly dissatisfied and cynical about company policy and will not work up to capacity. Even more, well-qualified workers will choose other companies because of the constant insecurity of such a production policy. As most aggregate models forecast alternations in labor conditions, this can cause problems among full-time workers. It introduces insecurities and uncertainty into the workplace.

Summary

Aggregate planning is an "intermediate-range capacity planning technique, usually covering a time frame of 2-12 months for a production process, in order to keep the costs of operations at a minimum." Companies use aggregate planning to help make decisions about their capacity because seasonal variations in demand are difficult to predict accurately. The main goal of the company is to match resources with the expected demand. This goal is achieved by taking into account a diverse amount of factors such as: decisions on output rates, overtime, employment levels and changes, inventory levels and changes, back orders, and subcontracting work.

A more extensive form of aggregate planning is sales and operations planning. *Sales and operations planning* are "intermediate-range decisions to balance supply and demand, integrating financial and operations planning". Sales and operations planning decisions are made using demand forecasts, financial limits, and organization's capacity constraints. The sales and operations plan carries information that impacts the supply chain.

Self-Assessment Questions

1) Which of the following is a computerized model that can be tested under different scenarios to identify acceptable solutions?
   a. test model
   b. difference model
   c. simulation model
   d. changing model
   e. growth model
   The answer is C.

2) Which of the following is **not** included in a planning sequence for aggregate planning?
   A. business plan
   b. aggregate plan
   c. master schedule
   d. master plan
   e. the entire above are included
   The answer is E.

3) What are the three most significant factors an organization has to consider when

choosing a start:

a. labor, demand, and time

b. company policy, flexibility, and costs

c. labor, time, and costs

d. company policy, flexibility, and demand

e. flexibility, time, and costs

The answer is B.

4) What are the key issue(s) in aggregate planning?

a. how to handle variations in demand

b. how to handle changes

c. how to manage cost

d. both a & b

e. none of the above

the answer is C.

5) what are the three types of aggregate planning?

a. long-range plans, intermediate plans, and short-range plans.

b. Long term demand, short term demand, economies of scale

c. minimization curves, inflections points in cost schedules, profit maximization

d. pricing models, statistical evaluation, tax shelter

e. freight costs, J-I-T delivery, logistics

The answer is A.

6) Which of the following are examples of service organizations that use aggregate planning?

a. airlines

b. hospitals

c. restaurants

d. A & B

e. all of the above

ANSWER: E

7) What are the three duties of master scheduling?

a) Provide delivery dates for orders, deal with problems, and schedule aggregate plans

b) Evaluate the impact of new orders, provide delivery dates for orders, and deal with problems

c) Schedule aggregate plans evaluate impact of new orders; deal with problems of previous orders

d) Evaluate the impact of old orders, provide delivery dates for new orders, and disaggregate plans

e) Deal with new and old problems, evaluate the impact of production, and provide delivery dates for new orders.

Answer: B

8) What are the differences between manufacturing and services for aggregate planning?

a. Demand for service can be difficult to predict

b. Capacity availability

c. Labor flexibility

d. Services occur when they are rendered

e. All of above

Answer is E.

9) Which of the following are Demand Options?

a) Pricing

b) Promotion

c) Using back orders

d) Creating new demand

e) all of the above

Answer: E

10) Which of the following is NOT a supply option?

a) Hire and lay off workers

b) Overtime/slack time

c) Subcontractors

d) Promotion

e) All of the above ARE supply options

Answer: D

Key Terms

Smoothing: refers to costs that result from changing production and workforce levels from one period to the next.

Bottleneck Problems: It is the inability of the system to respond to sudden changes in demand as a result of capacity restrictions.

Planning Horizon: The number of periods for which the demand is to be forecasted, and hence the number of periods for which workforce and inventory levels are to be determined, must be specified in advance.

Treatment of Demand: Aggregate planning methodology requires the assumption that demand is known with certainty. This is simultaneously a weakness and a strength of the approach.

UNIT IV
SCHEDULING AND ROUTING

Introduction

Operations (or production) are the process and activities for transforming resources into finished services and goods for customers. The operations function creates four kinds of utility – time utility, place utility; possess utility, and form utility – to meet customer needs.

Performing a service is different from manufacturing a good in several key ways: the raw material for service production includes the people who are seeking the service. In addition, most services are intangible, customized, and cannot be stored. Because of these characteristics, service providers generally focus on the customer service, often acknowledging the customer as part of the operations process.

Operations planning for both goods and services involve the analysis of five key factors: *Capacity planning* requires determining how much of a product a firm must be able to produce. *Location planning* involves choosing among potential facility sites. *Layout planning* entails designing an effective, efficient facility. *Quality planning* ensures that products meet a firm's quality standards. *Methods planning* involve identifying specific production steps and methods for performing them.

What is an operation scheduling?

Scheduling is actually concerned with establishing both the timing and the use of resources within a firm. First, keeping in view the estimated future demand of the final product, aggregate planning is done for long time horizon usually for 1-3 years. In turn, this long term plan is broken down in master production schedules for shorter time period. Master production schedule is a document that comprises of the complete information about the quantity and time of different products to be produced. On the basis of this, demand for the raw material, components etc (known as secondary demand) are estimated under the material requirement planning system. Finally, very short term schedules are prepared which establish both the timing and the use of resources within a firm.

In fact, schedules are the operations plans which are executed at lowest (shop floor) level.

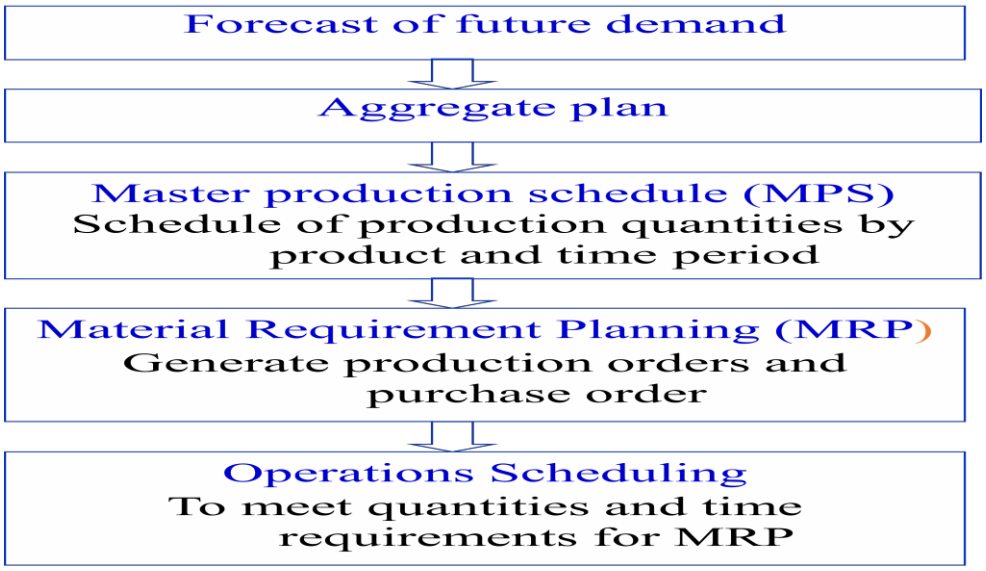
Thus, schedules ensure timely production and delivery of products and the availability of required quantity of resources when they are actually required without interrupting the

production.

Similarly, operations control is also a mechanism which is exercised to ensure the continuous production as per the planned one. In case of any discrepancy, taking an immediate remedial action in order to produce defect free products on scheduled time

Concept of Scheduling:

As discussed above, the main purpose of preparing the operations schedule is to exercise the better control over the entire process. Schedules are of immense importance as far as timing and availability of adequate resources is concerned.



In the figure above, it is easy to understand the way aggregate plans are finally broken down into operations schedules at shop floor level. Some of the objectives of operations schedules have been summarized as below:

- Meet due date;
- Minimize *Work in Progress (WIP)* inventory;
- Minimize the average flow time through the systems;
- Provide for high machine/worker (time) utilization (minimize idle time);
- Reduce setup cost;
- Minimize production and worker costs;
- Consideration of due dates and avoiding delayed completion of job;
- Taking care of throughput time; to minimize the time a job spends in the system

Principles of Scheduling

Most of the time, scheduling is done in view of the principles:

- ✓ Schedule jobs in continuation;
- ✓ After starting a job, finish it;
- ✓ Focus on bottleneck;
- ✓ Real time feedback, real time adjustments;
- ✓ Knowledge of capacity of machines and workers;
- ✓ Continuous enhancement of product and process;

Approaches to Scheduling:

There are mainly two types of approaches which are commonly used:

1. *Forward scheduling:* in forward scheduling, the scheduler schedules all activities forward in time.
   (a) Jobs are given earliest available time slot in operation;
   (b) Usually excessive WIP results.

2. *Backward scheduling:* In backward scheduling, the scheduler begins with a planned date and moves backward in time.
   (a) Start with due date and work backward through operations reviewing lead times;
   (b) Less WIP but must have accurate lead time.

Scheduling Decisions:

Whenever, different types of products are produced using the same facility, complete changeover of the system is required. Changeover is the cost of changing a processing step in a production system from one job to another. Such cost corresponds to changing machine settings, getting job instructions, changing material and changing tools.

In case of changeover, one has to be very cautious in changing the schedules also. When there is any changeover in the organization, in addition to operations schedules, the components of production system that need to be changed are as followings:

- ❖ INPUTS: When there is a change over in a organization production system inputs are changed according to the production. Inputs include raw materials, components etc;
- ❖ OUTPUT: When inputs are changed so automatically outputs are also changed in the production system;
- ❖ LOGISTICS: logistics are also will be changed in the changeover of production system;
- ❖ COST: Cost is the main factor in change over. As cost may increase or decrease in the changeover of production system in the organization;

- LABOUR: Labour is also important factor as which labour will do which it has to be assigned;
- TIME: In changeover production system in an organization time factor matters the most. As it is not be same that first production done in a given time will be done as of same time in other production. The time may vary now.

Elements of Shop Floor Scheduling

As we know by the discussion so far, schedules are the operations plans which are executed at the lowest (shop floor) level. The classic approaches to shop floor scheduling focuses on the following elements:

- Job arrival patterns: static or dynamic
  - Static: jobs arrive in batch;
  - Dynamic: jobs arrive over time interval according to some statistical distribution.
- Numbers and variety of machines in the shop floor
  - If there is only one machine or if a group of machines can be treated as one machine, the scheduling problem is much more simplified;
  - As number of variety of machines increase, the more complex the scheduling problems is likely to become.
- Ratio of workers to machines
  - Machine limited system: more workers than machine or equal number workers and machines;
  - Labor-limited system: more machines than worker.
- Flow pattern of jobs: flow shop or job shop
  - Flow shop: all jobs follow the same paths from one machine to the next;
  - Job shop: no similar pattern of movement of jobs from one machine to the next

    Job sequencing
  - Sequencing or priority sequencing: the process of determining which job is started first on some machines or work center by priority rule;
  - Priority rule: the rule used for obtaining a job sequencing;

- Priority rule evaluation criteria
  - To meet corresponding objectives of scheduling;
  - Common standard measures:
  - Meeting due date of customers or downstream operations;
  - Minimizing flow time (the time a job spends in the shop flow);
- Minimizing WIP;
- Minimizing idle time of machines and workers (Maximizing utilization).

Loading:

- Loading is concerned with assigning jobs to work centers and corresponding to various machines in the work centers.
- Approaches to Loading work centers
  a) Infinite Loading: In infinite loading jobs are assigned to work centers without considering the capacity of the work centers
  b) Finite Loading: Finite Loading estimates the actual start and stop time of each job at each work centers.

Sequencing:

Sequencing means determining the order in which jobs are processed. The order is also require for work processed at individual workstation. If work centers are heavily loaded and jobs are lengthy, the situation can become complicated. The order of processing is vital when it comes to the cost of waiting to be processed and the cost of ideal time at work centers.

Rules for Sequencing:

1. **FCFS** ***(first come-first served)***

1. Jobs are processed in the sequence in which they entered the shop;
2. The simplest and nature way of sequencing as in queuing of a bank

2. **SPT** ***(shortest processing time)***

1. Jobs are sequenced in increasing order of their processing time;
2. The job with shortest processing time is first, the one with the next shortest processing time is second, and so on;

3.* EDD *(earliest due date)

1. Jobs are sequenced in increasing order of their due dates;
2. The job with earliest due date is first, the one with the next earliest due date is second, and so on;

4.* CR *(Critical ratio)

1. Critical ratio is the remaining time until due date divided by processing time;
2. Scheduling the job with the smallest CR next;
3. CR provides the balance between SPT and EDD, such that the task with shorter remaining time and longer processing time takes higher priority;
4. CR will become smaller as the current time approaches due date, and more priority will be given to one with longer processing time;
5. For a job, if the numerator of its CR is negative (the job has been already later), it is naturally scheduled next;
6. If more than one jobs are later, higher priority is given to one that has shorter processing time (SPT).

5. Least work remaining (LWR)

It is an extension of SPT. It indicates that work be scheduled according to the processing time remaining before the job is considered to be complete.

6. Fewest operations remaining (FOR)

It is another form of SPT. It sequences jobs based on the number of successive operations remaining until the job is considered.

7. Slack time (ST)

Slack is determined by subtracting the sum of set-up and processing times from the time remaining until the job due date. Jobs are processed in order of the smallest amount of slack.

8. Slack time per operation (ST/O)

The slack time is divided by the number of operations remaining until the job is complete with the smallest values being scheduled first.

9. Next queue (NQ)

It depends on the machine utilization. It considers queues at each of the succeeding

work centers at which the jobs will go.

10. **Least set –up (LSU)**

    It maximizes utilization. Least set-up selects first the job minimizes changeover time on given machine.

Functions of Schedules:

The following functions must be performed in scheduling and controlling a shop floor:

- Allocating orders, equipment's, and personnel to work centers or other specified location-Short term capacity planning;
- Determining the sequence of orders (i. e. job priorities);
- Initializing performance of the scheduled work, commonly termed the dispatching of jobs;
- Shop-floor control, involving
  - Reviewing the status and controlling the progress of orders as they are being worked on;
  - Expediting the late and critical orders;
- Revising the schedules in light of changes in order status.

Operations Controlling

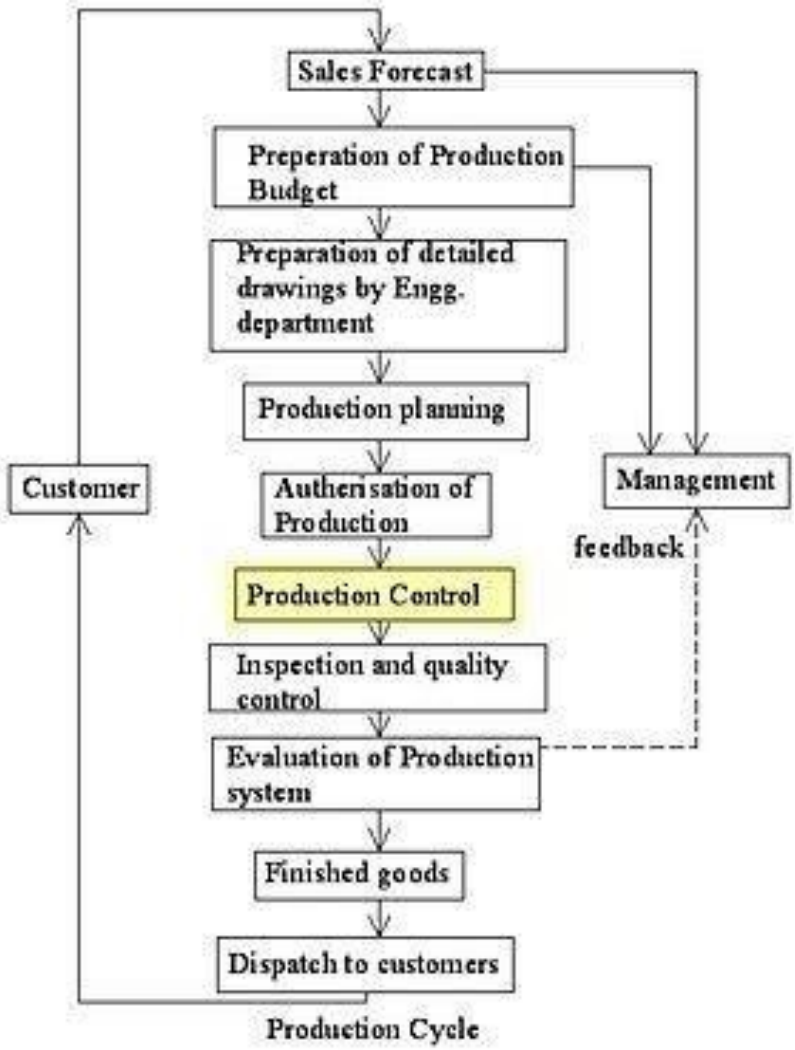
Operational controlling is used to regulate the internal processes necessary to monitor and direct of the company in the short term. It allows making decisions related to ongoing business operations. The main tasks of operational controlling include:

- Controlling of the results,
- Liquidity planning,
- Monitoring of profitability,
- Improving effectiveness of use of existing resources.

The process of operational controlling allows converting strategic plans in the operational plans. These plans must be tailored to specific units that make up the whole company. The whole process takes often place in the so-called "budgeting process".

Operational control normally takes the form of budgetary control, and is performed by comparing the short-term performance of organizational units with those established in the

budget. Then managers analyze the deviations of actual values from the values set in goals for specific unit and the whole company.



In the figure as above, production/ operation control mechanism is self explanatory. The whole system is mainly divided into three elements:

- Internal reporting system;
- Budgetary control;
- Operational planning (budgeting).

It is easy to see in the figure that there are three stages in production control function:

a) **PLANNING STAGE**: This stage deals with the activities such as product planning, forecasting of the demand on the basis of past trends;

b) **ACTION STAGE**: It is concerned with the real implementation of the plan. It begins with the dispatching function, which deals with the progress of the work or job;

c) **MONITORING STAGE**: In this stage, the planned activities are controlled and

monitored by using various techniques such as inventory control, tool control, cost control, quality control. Reporting helps in controlling the whole process.

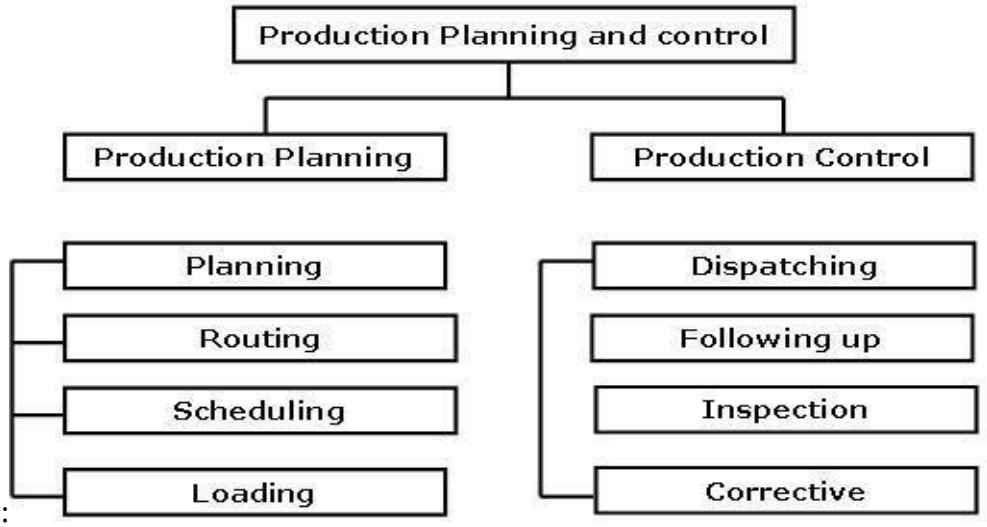
Characteristics of Control System:

Some important characteristics of control system may be mentioned as hereunder:

- Control is a continuous process
- Control is a management process
- Control is embedded in each level of organizational hierarchy
- Control is forward looking
- Control is closely linked with planning
- Control is a tool for achieving organizational activities
- Control is an end process
- Control compares actual performance with planned performance*
- Control point out the error in the execution process
- Control helps in minimizing cost
- Control helps in achieving standard
- Control saves the time

Elements of Operations Control

As we have already discussed in chapter one that production plans are prepared in advance at top level whereas, production control is exercised at machine shop floor (bottom level) where actual production is taking place. Some important elements of PPC have been depicted in the figure as below:



The important elements may be listed as following:

1. **Materials:** planning for procurement of raw material, component and spare

parts in the right quantities and specifications at the right time from the right source at the right place. Purchasing, storage, inventory control, standardization, variety reduction, value analysis and inspection are the other activities associated with material.

2. **Method:** choosing the best method of processing form several alternatives. It also includes determining the best sequence of operations (process plan) and planning for tooling, jigs and fixtures etc.
3. **Machines and equipment:** manufacturing methods are related to production facilities available in production systems. It involves facilities planning, capacity planning, allocations, and utilization of plant and equipment, machines etc.
4. **Manpower:** planning for manpower (labour and managerial levels) having appropriate skills and expertise.
5. **Routing;** determining the flow of work material handling in the plant, and sequence of operations or processing steps. This is related to consideration of appropriate shop layout plant layout, temporary storage location for raw materials, component and semi-finished goods, and of materials handling system.

   Route Sheet: a route sheet is a document providing information and instructions for converting the raw material in finished part or product. It defines each step of the production operations and lay down the precise path or route through which the product will flow during the conversion process. Route sheet contains following information:

a) The operation required at their desired sequence
b) Machines or equipment to be used for each operations
c) Estimated set-up time and operation time per piece
d) Tools, jigs, and fixtures required for operations
e) Detailed drawings of the part, sub-assemblies and final assemblies
f) Specification, dimensions, tolerances, surface finishes and quality standard to be achieved
g) Specification of raw material to be used
h) Speed, feed etc. to be used in machines tools for operations to be carried on.
i) Inspection procedure and metrology tools required for inspection
j) Packing and handling instructions during movement of parts and subassemblies through the operation stages.

6. **Estimating:** Establishing operation times leading to fixations of performance

standards both for worker and machines. Estimating involves deciding the quantity of the product which needs to be produced and cost involved in it on the basis of sale forecast.

Estimating manpower, machine capacity and material required meeting the planned production targets are like the key activities before budgeting for resources.

7. **Loading:** machine loading is the process of converting operation schedule into practices in conjunctions with routing. Machine loading is the process assigning specific jobs to machines, men, or work centers based on relative priorities and capacity utilization. Loading ensures maximum possible utilization of productive facilities and avoid bottleneck in production. It's important to either overloading or under loading the facilities, work centers or machines to ensure maximum utilization of resources.

8. **Scheduling:** scheduling ensure that parts and sub-assemblies and finished goods are completed as per required delivery dates. It provides a timetable for manufacturing activities.

Purpose of scheduling:

a) To prevent unbalance use of time among work and centers and department.To utilize labour such a way that output is produced within established lead time or cycle time so as to deliver the products on time and complete production in minimum total cost.

9. **Dispatching:** This is concerned with the execution of the planning functions. It gives necessary authority to start a particular work which has already planned under routing and scheduling functions. Dispatching is release of orders and instructions for starting of production in accordance with routing sheet and scheduling charts.

10. **Inspection:** This function is related to maintenance of quality in production and of evaluating the efficiency of the processes, methods and labours so that improvement can be made to achieve the quality standard set by product design.

11. **Evaluating:** The objective of evaluating is to improve performance. Performance of machines, processes and labour is evaluated to improve the same.

12. **Cost control:** Manufacturing cost is controlled by wastage reduction, value analysis, inventory control and efficient utilization of all resources.

Requirements for an effective Operations Control System:

In an organization, control based operations system can be effective only if the following aspects are given due considerations before implementation:

a) Appropriate organization structure with sufficient delegation of authority and responsibility at various levels of manpower.
b) Right person should be deputed at right place for right job.
c) Maximum level of standardization of inventory, tooling, manpower, job, workmanship, equipment, etc.
d) Appropriate management decision for production schedule, materials controls, inventory and manpower turnover and product mix.
e) Flexible production system to adjust any changes in demand, any problem in production or availability of materials maintenance requirements, etc
f) Estimation of accurate leads times for both manufacturing and purchase.
g) Management information system should be reliable, efficient and supporting.
h) Capacity to produce should be sufficient to meet the demand.
i) The facility should be responsive enough to produce new products change of products mix and be able to change the production rates.

The above elements are very important and necessary to make the production planning system effective and efficient.

Utility of Operational Controlling System:

The implementation of control based operation system yields various advantages to any organization for various functional activities, which include the following:

a) **Last hour rush is avoided:** Production is well planned and controlled as per the given time schedules. Therefore, production control reduces the number of emergency order and overtime works on plant and thus reduces the overheads.
b) **Problems areas of bottleneck get reduced:** The incomplete work or work-in-transit does not get piled up because production control balances the line and flow

of work.

c) **Cost reduction:** An appropriate production control increases the men-machines utilization, which maintains in process inventories at a satisfactory level, leads to a better control on raw material inventories, reduces costs of storage and materials handling, helps in maintaining quality and limits rejections and thus ultimately reduces the unit cost of production.

d) **Optimum utilization of resources:** It reduces the time loss of the workers waiting for materials and makes most effectives use of equipment.

e) **Better coordination of plants activities:** PPC coordinates the activities of the plant that leads to control concerted effort by workforce.

f) **Benefits to workers:** PPC results into better efficiency and productivity, which leads to adequate wages stable employment, job security, improved working conditions increased job satisfaction and ultimately high morale.

g) **Improved services to customers:** PPC leads to better services to the customers as it ensures production in accordance with the time schedules and therefore, deliveries are made as per the committed schedules.

Scope of Operational Controlling System:

a) *Nature of Inputs:* To manufacture a product, different types of inputs are used. The quality of the product depends upon the nature of the inputs are used. Hence the planning is done to determine the nature of various types of inputs which is a complicated process.

b) *Quantity of Inputs:* To achieve a level of production, determination of quantity of the inputs and their composition is very important. A product can be prepared only when there is an estimate of the required composition of inputs.

c) *Proper Coordination:* It ensures the proper coordination among the workforce, machines and equipment. This leads to avoidance of wastages and smooth flow of production.

d) *Better Control:* Production planning is the method of control. For a better control, planning is a precondition. Only then, one can compare the performance and calculate the deviations which lead control of the production.

e) *Ensure Uninterrupted Production:* The planning of materials ensures the regular supply of raw materials and other components. The regular flow of materials and supplies are helpful in the uninterrupted production.

f) *Capacity Utilization:* There is a need to use the available resources effectively. It is

helpful in bringing down various costs of production.

g) *Timely Delivered:* If there is good production planning and control, there will be timely production and the finished product will be rushed to the market in time. This also ensures the better relationship with the customers.

Design of Operational controlling system:

The complete design process has been explained in brief as follows:

- Determination of the time, scope and field of controlling;
- Preparation - setting goals and plans;
- Selection of parameters, measures and indicators;
- Providing proper information sources across organization;
- Determining the procedure for monitoring deviations;
- Establishing rules for decision-making process;
- A decision on the implementation of the system;
- Determination of the detailed time schedule and financial resources needed for implementation;

Operational controlling provides broad source of the information necessary to control main economic processes. This information pertains primarily of present business, performance and resource utilization. Operational controlling is closely linked and integrated with strategic controlling.

Summary

Operations function in a manufacturing or service organization is concerned with the transformation of some inputs into some outputs that have some value for the end users. In manufacturing organizations, there are many types of production systems namely mass, process, batch and job production systems. The selection of system depends upon mainly two things: i) nature of the product, ii) type of manufacturing process.

Scheduling is the final planning that occurs before the actual execution of the plan. Production planners track the performance of operations in meeting the planned schedule. This is critical because the master scheduler evaluates production planners on the level of customer service achieved for their product responsibilities.

- ✓ Schedules are essential to shop floor supervisors. The amount of time to complete a job is often determined by a time standard. If the time standards are inaccurate (either too stringent or too loose), the worker's morale may be affected.

- ✓ Customers often need to know when the service will be provided (cable installers) so that the customer is available. Customers often link quality of service with adherence to the schedule (if the company delivers on time, everything is fine).
- ✓ Scheduling executes a company's strategic business plan and affects functional areas throughout the company
- ✓ Accounting relies on schedule information and completion of customer orders to develop revenue projections
- ✓ Marketing uses schedule effectiveness measurement to determine whether the company is using lead times for competitive advantage
- ✓ Information systems maintains the scheduling database
- ✓ Operations uses the schedule to maintain its priorities and to provide customer service by finishing jobs on time

  Different kinds of environments need different scheduling techniques. Scheduling in the high-volume environment is typically done through line design and balancing. Scheduling in a low-volume environment typically involves the use of priority rules.

  - Shop loading techniques included infinite or finite loading. Finite loading loads jobs up to a predetermined capacity level. Loading can be done using forward or backward scheduling
  - Priority rules are used to make scheduling decisions. SPT always minimizes mean job flow times, mean job lateness, and average number of jobs in system. Rules related to due dates tend to minimize the maximum tardiness of the jobs.

  Operations control is a mechanism to monitor the execution of the plans. It has several important functions:

  a) Making sure that all activities are started at planned places and planned times.
  b) Observing progress of the operations and recording it properly.
  c) Analyzing the recorded data with the plans and measuring the deviations.
  d) Taking immediate corrective actions to minimize the negative impact of deviations from the plans.
  e) Feeding back the recorded information to the planning section in order to improve future plans.

Key Terms:

- **Scheduling:** is the timetable for various activities;
- **Estimating:** is a process of setting operation times after fixing standards both for worker and machines;
- **Loading:** is the process of converting operation schedule into practices;
- **Routing**: is the process of determining the flow of work material handling in the plant, and sequence of operations

Self-assessment Questions:

a) Define scheduling. Discuss the objectives and principles of scheduling.

b) Explain in detail the scheduling decisions.

c) Discuss the elements of shop floor scheduling.

d) Define operation control. Discuss the elements of operations control.

e) Explain in detail the characteristics of an operational control mechanism.

UNIT V

DISPATCHING

Introduction

By the time, we all have understood the meaning of production. Production may be understood as the step-by-step conversion of one form of material into another form through chemical and mechanical process to create or enhance the utility of the product to the user. Some examples of production are: manufacturing standardized products like cars, bus, motorcycle, radio, TV etc.

Production system is actually a combination of various methods, procedures, arrangements and different functions that are required to accumulate (gather) the inputs, process or reprocess the inputs and deliver the marketable output (goods). Production system utilizes materials, funds, infrastructure and labour to produce the required output inform of goods.

There are different types of production processes. The selection of production process mainly depends upon the variety of the products to be produced, volume of production and degree of flexibility required.

a) Job shop
- For small scale production

b) Batch
- For moderate volume

c) Repetitive/assembly line
- For high volumes of standardized goods or services

d) Continuous
- For very high volumes of non-discrete goods

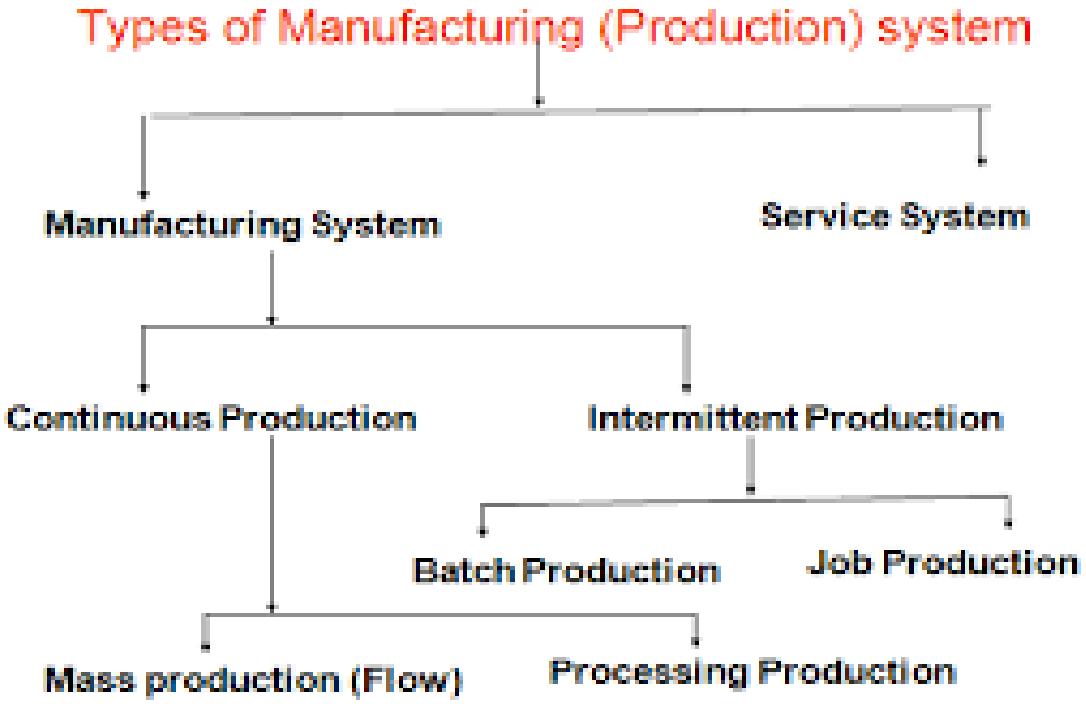
In this chapter, the main focus is on the production of high volumes of standardized goods. For such types of goods, mainly mass/ continuous production system is used.

This chapter also deals with production planning and control aspects for the mass/continuous production system in detail. The most important aspect of continuous (which is also known as assembly line production) production is the balancing of assembly line. This will be discussed in much detail with suitable examples.

An Overview of Different Types of Production Systems:

Once the process decision is taken, next is type of production system. Depending upon the process, production systems may be categorized as shown in the diagramme below.

Types of Manufacturing/Production Systems:



In order to develop a better understanding, each type of production system has been discussed along with its characteristics, merits and limitations.

Job Shop Production:

- Job shop production are characterized by manufacturing of one or few quantity of products designed and produced as per the specification of customers within prefixed time and cost.
- The distinguishing feature of this is low volume and high variety of products.
- A job shop comprises of general purpose machines arranged into different departments.
- Each job demands unique technological requirements, demands processing on machines in a certain sequence.

Characteristics

The Job-shop production system is followed when there is:

- High variety of products and low volume.
- Use of general purpose machines and facilities.
- Highly skilled operators who can take up each job as a challenge because of

uniqueness.

- Large inventory of materials, tools, parts.
- Detailed planning is essential for sequencing the requirements of each product, capacities for each work centre and order priorities.

Advantages

Following are the advantages of job shop production:

- Because of general purpose machines and facilities variety of products can be produced.
- Operators will become more skilled and competent, as each job gives them learning opportunities.
- Full potential of operators can be utilised.
- Opportunity exists for creative methods and innovative ideas.

Limitations

Following are the limitations of job shop production:

- Higher cost due to frequent set up changes.
- Higher level of inventory at all levels and hence higher inventory cost.
- Production planning is complicated.
- Larger space requirements.

Batch Production:

Batch production is defined by American Production and Inventory Control Society (APICS) *"as a form of manufacturing in which the job passes through the functional departments in lots or batches and each lot may have a different routing."* It is characterized by the manufacture of limited number of products produced at regular intervals and stocked awaiting sales.

Characteristics

Batch production system is used under the following circumstances:

- When there is shorter production runs.
- When plant and machinery are flexible.
- When plant and machinery set up is used for the production of item in a batch and change of set up is required for processing the next batch.
- When manufacturing lead time and cost are lower as compared to job order production.

Advantages

Following are the advantages of batch production:

- Better utilization of plant and machinery.
- Promotes functional specialization.
- Cost per unit is lower as compared to job order production.
- Lower investment in plant and machinery.
- Flexibility to accommodate and process number of products.
- Job satisfaction exists for operators.

Limitations

Following are the limitations of batch production:

- Material handling is complex because of irregular and longer flows.
- Production planning and control is complex.
- Work in process inventory is higher compared to continuous production.
- Higher set up costs due to frequent changes in set up.

Continuous Production:

Production facilities are arranged as per the sequence of production operations from the first operations to the finished product. The items are made to flow through the sequence of operations through material handling devices such as conveyors, transfer devices, etc.

Characteristics

Continuous production is used under the following circumstances:

- Dedicated plant and equipment with zero flexibility.
- Material handling is fully automated.
- Process follows a predetermined sequence of operations.
- Component materials cannot be readily identified with final product.
- Planning and scheduling is a routine action.

Advantages

Following are the advantages of continuous production:

- Standardization of product and process sequence.
- Higher rate of production with reduced cycle time.
- Higher capacity utilization due to line balancing.
- Manpower is not required for material handling as it is completely automatic.

- Person with limited skills can be used on the production line.
- Unit cost is lower due to high volume of production.

Limitations

Following are the limitations of continuous production:

- Flexibility to accommodate and process number of products does not exist.
- Very high investment for setting flow lines.
- Product differentiation is limited

Mass Production:

Henry ford designed his first moving assembly line. In 1913, and revolutionized the manufacturing processes. It was Henry's intention to produce largest no. of cars, to the simplest design, for the lowest possible cost. The assembly line became the benchmark for mass production methods around the world.

Mass Production is the name given to the method of producing goods in large quantities at low cost per unit. But mass production, although allowing lower prices, does not have to mean low quality production. Instead mass produced goods as standardized by means of precision manufactured, interchangeable parts.

Machine tools and interchangeable parts the material basis for mass production was laid by the development of the machine tool industry that is, the making of machines to make machines.

The assembly line is an arrangement of machines, tools and workers in which a product is assembled by having each perform a specific, successive operation on an incomplete unit as it passes by in a series of stages organized in a direct line.

Example of Mass Production systems:

Production of biscuits in a factory can be taken as an example of mass production. At every stage a particular operation is performed using a specific machine. As is shown below, packs of identical biscuits are produced in an industrial unit

Stage: 1: MIXING: Flour + fat + sugar + bicarbonate + additives

Stage: 2: MOULDING: Dough is laminated in a laminator

Stage: 3: GAUZE ROLLS: Laminated dough is cut as per size and shape

Stage: 4: BAKING: Biscuits cut into shapes are baked in the oven

Stage: 5: COOLING: Biscuits are cooled in conveyors once they are baked

Stage: 6: PACKAGING: The final product is then packed into pouches and cartons

Characteristics

- Achieve economies of scale by producing in very large quantity
- Standardizing products
- Developing efficient processes
- Producing more of each product at one time
- Selling at lower price

Advantages

- Higher rate of production with reduced cycle time.
- Higher capacity utilization due to line balancing.
- Less skilled operators are required.
- Low process inventory.
- Manufacturing cost per unit is low.
- Reducing direct labour cost
- Accuracy in product design and quality

Limitations

- Breakdown of one machine will stop an entire production line.
- Line layout needs major change with the changes in the product design.
- High investment in production facilities.
- The cycle time is determined by the slowest operation.

Concept of Standardization

Standardization means producing maximum variety of products from the minimum variety of materials, parts, tools and processes. It is the process of establishing standards or units of measure by which extent, quality, quantity, value, performance etc., may be compared and measured.

Factors encouraging standardization are:

- ✓ Economies of scale in production and marketing
- ✓ Consumer mobility - the more consumers travel the more is the demand
- ✓ Technology
- ✓ Image, for example "Japanese", "made in".

Advantages of Standardization to various departments in the company:

Benefits to Manufacturing Department:

- Lower unit cost.
- Better quality products.
- Better methods and tooling.
- Increased interchangeability of parts.
- Better utilization of manpower and equipment.
- Accurate delivery dates.
- Better services of production control, stock control, purchasing, etc.
- More effective training.

Benefits to Production Planning Department:

- Scope for improved methods, processes and layouts.
- Opportunities for more efficient tool design.
- Better resource allocation.
- Reduction in pre-production activities.

Benefits to Production Control Department:

- Well proven design and methods improve planning and control.
- Accurate delivery promises.
- Fewer delays arise from waiting for materials, tools, etc.
- Follow-up of small batches consumes less time.

Benefits to Purchase and Stock Control Department:

- Holding of stock of standard items leads to less paper work and fewer requisitions and orders.
- Storage and part location can be improved.
- Newer techniques can be used for better control of stocks.
- Because of large purchase quantities involved, favorable purchase contracts can be made.

Benefits to Quality Control Department:

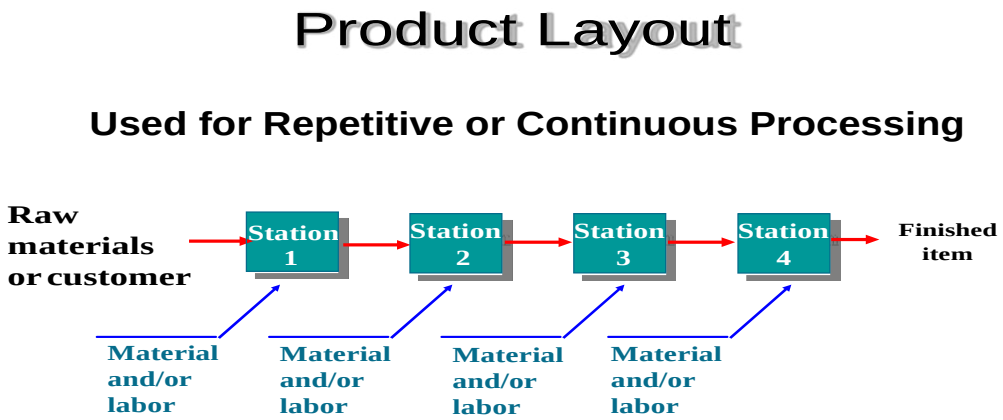
- Better inspection and quality control is possible.
- Quality standards can be defined more clearly.
- Operators become familiar with the work and produce jobs of consistent quality.

Other Benefits:

- Work study section is benefited with efficient break down of operations and effective work measurement.
- Costing can obtain better control by installing standard costing.
- More time is available to the supervisors to make useful records and preserve statistics.
- Reduced reductions and scrap.
- Helps supervisors to run his department efficiently and effectively.

Line Balancing Rules in Mass/ Assembly Line Production:

In mass production system that is also known as assembly line production, since the product is standardized and volume of production is very high, therefore, all man power, equipments and machines need to be arranged in a definite sequence as per the requirement of the product to be produced. In mass production, production takes place in a line as shown in the figure below. *The assembly line is a production line where material moves continuously through a series of workstations where assembly work are performed.*



Advantages of Assembly Line Production:

- High rate of output
- Low unit cost
- Labor specialization
- Low material handling cost
- High utilization of labor and equipment
- Established routing and scheduling
- Routine accounting, purchasing and inventory control

Line Balancing Problem in Assembly Line Production:

Since in assembly line production, all man power, machines, equipments and workstations are arranged in a line as per the product process requirements, it is necessary that this line should be balanced. This means that time taken at each work station must be equal and preferably equal to cycle time, otherwise continuous production may be hampered.

Therefore, there is a pressing need to arrange the individual processing and assembly tasks at the workstations so that the total time required at each workstation is approximately the same. It is almost impossible to reach perfect balance.

Things to Consider in Line Balancing:

- Sequence of tasks is restricted, there is a required order, called precedence constraints
- There is a production rate needed, i.e. how many products needed per time period
- Design the line to meet demand and within constraints

Terminology and Definitions:

- Minimum Work Element
- Total Work Content
- Workstation Process time
- Cycle Time
- Precedence Constraints
- Balance Delay

Cycle Time:

- Time between parts coming off the line
- Ideally, the production rate, but may need to be adjusted for efficiency and down time
- Established by the bottleneck station, that is station with largest time

Precedence Constraints:

- Generally given, determined by the required order of operations
- Draw in a network style for understanding
- Cannot violate these, an element must be complete before the next one is started

Balance Delay:

Measure of line inefficiency due to imbalances in station times

$$d = \frac{nT_c - T_{wc}}{nT_c}$$

Method- Largest candidate Rule:

- List elements in descending order of T
- Assign elements to first station, from top to bottom of list, minding constraints, and not causing sum to exceed cycle time
- Continue assigning elements to stations where each station < cycle time, largest assigned first, until all assigned

Example of Line Balancing in Continuous/ Mass Production:

The above discussed rule and complete process of line balancing may be understood better with the help of following example:

IFFCO Fertilizer Limited plant manager on the basis of forecast made by sales department; wants its production line to be designed to make 2,400 spreaders per week. The plant will operate 40 hours per week.

(Q1.) What should be the line's cycle time or throughput rate per hour be?

Throughput rate/hr = 2400 / 40 = 60 spreaders/hr

Cycle Time = 1/Throughput rate= 1/60 = 1 minute = 60 seconds

Assume that in order to produce the new fertilizer spreader on the assembly line requires doing the following steps in the order specified:

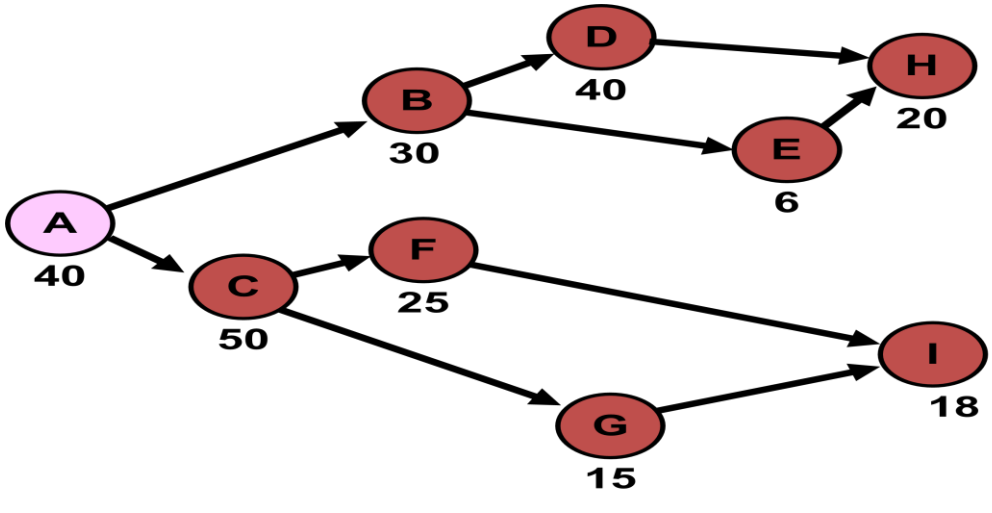
Work Element	Description	Time (sec)	Immediate Predecessor(s)
A	Bolt leg frame to hopper	40	None
B	Insert impeller shaft	30	A
C	Attach axle	50	A
D	Attach agitator	40	B
E	Attach drive wheel	6	B
F	Attach free wheel	25	C
G	Mount lower post	15	C
H	Attach controls	20	D, E
I	Mount nameplate	18	F, G
		Total 244	

(Q2.) What is the total number of stations or machines required?

TM (Total machines) = total production time / cycle time = 244/60 = 4.067 or ≈ 5

(Q3.) Drawing Precedence Diagramme:

The figure shows the complete diagram. We begin with work element A, which has no immediate predecessors. Next, we add elements B and C, for which element A is the only immediate predecessor. After entering time standards and arrows showing precedence, we add elements D and E, and so on. The diagram simplifies interpretation. Work element F, for example, can be done anywhere on the line after element C is completed. However, element I must await completion of elements F and G.



***(Q4.)* Allocating work or activities to stations or machine**

- The goal is to cluster the work elements into workstations so that
  1. The number of workstations required is minimized
  2. The precedence and cycle-time requirements are not violated
- The work content for each station is equal (or nearly so, but less than) the cycle time for the line
- Trial-and-error can be used but commercial software packages are also available

Solution:

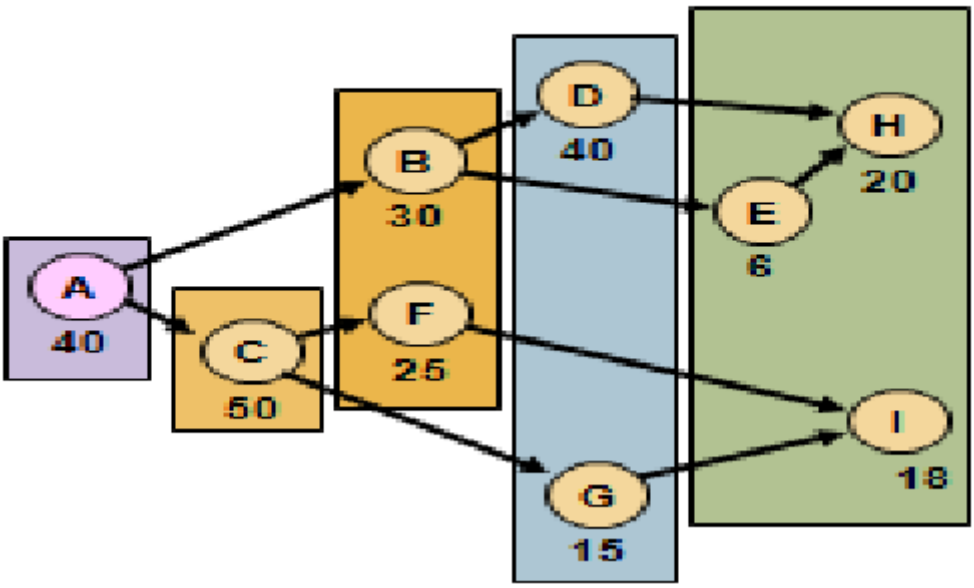
The theoretical minimum number of stations (TM) = $\Sigma\, t / c$

Where,

$\Sigma\, t$ = total time required to assemble each unit

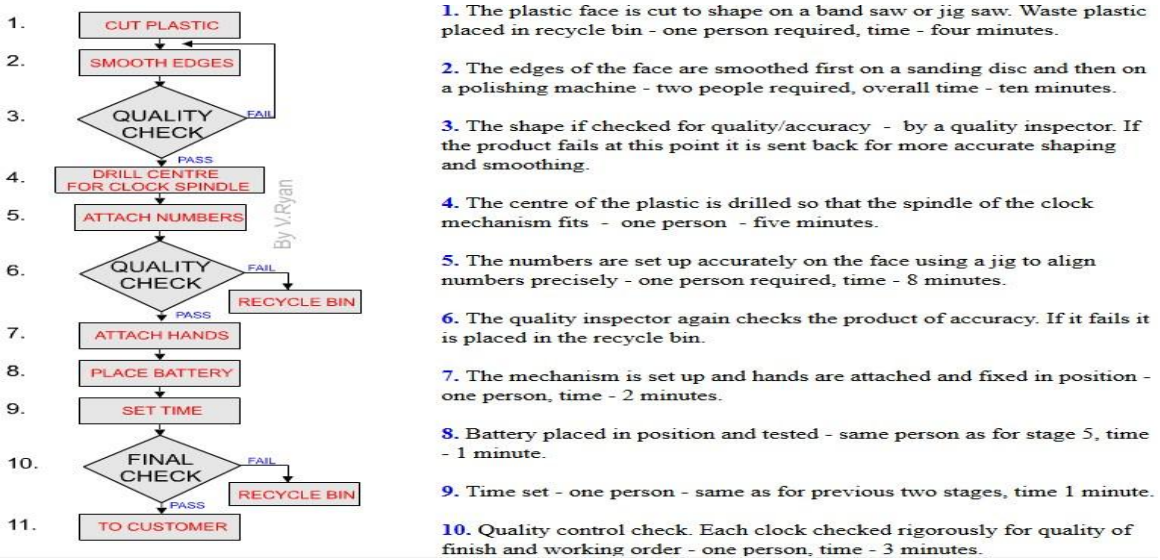
The minimum number of workstations is 5 and the cycle time is 60 seconds, so figure below represents an optimal solution to the problem.

Work station 1 includes machine A, station 2 machine C, station 3 machine B & F, station 4 machine D & G, station 5 machine E,H & I respectively.



(Q 5.) Calculating Line Efficiency:

Now calculate the efficiency measures of a five-station solution:



Efficiency = $\Sigma\, t / nc * (100) = 244/ 5 \text{ x } 60 = 81.3\%$

Balance delay (%) = 100 – Efficiency = 100% - 81.3% = 18.7%

Idle time = $nc - \Sigma\, t = 5(60) - 244 = 56$ seconds

Design of an Assembly Line:

The assembly line balancing aims to minimize the idle time of machines. It means the reduction in the number of operators to perform a task. The entire assembly is divided into parts. An assembly line may follow any of the following models:

- **Modular Production:** Such a model is followed to introduce variety in the mass production system. In such a system, a minimum number of parts or processes are developed and produced. These are called modules. They can be combined in a different ways to offer variety.
- **Group Technology:** In a group technology plant layout, parts required in a particular operation are put under different groups. Machines are arranged in such a way that each machine is assigned to the production of one group.
- **Automation:** Machines, material and control are integrated in such a system.

A Simple Production Line for Assembly of a Clock Face:

It is convenient for the readers to have an idea from the flow chart as shown below that how all facilities are arranged in line form in an assembly line production.

Parameters of Production Planning in Assembly Line Production:

Production planning is related to making the plans i.e. the detailed scheduling of jobs, assigning of workloads to machines (and people), routing, and the actual flow of work through the system. As production is an organized activity of converting row materials into useful products, plans are made in coordination with different departments: such as production, marketing, logistics, warehouse and other departments depending upon the nature of organization. Planning is always done on the basis of the aim and objective of the production process while keeping in mind the available resources.

Production control is concerned with the effective implementation of the plans. Planning and control are the two most basic, integral and interdependent functions. The plan for an activity is drawn before executing the design or the process. The planning part is always pre operation. Control is done after execution or implementation of the planned layout and procedure. Production planning and control can be viewed as nervous system of the production operation.

A proper control system has to be in place for the best utilization of resources and information before production and analyzing and appraising the performance of labor and equipment after the production is complete. A critical assessment is possible only by setting up a control mechanism.

The basic objectives of production planning and control are:

- To evaluate and appraise the resources at input stage, like the raw materials, labor, data, information and methods required for a production process and to estimate their quantity and quality
- To implement the preplanned process in such a way that optimum production is achieved with maximum efficiency and minimum wastage.

Benefits of Production Planning and Control:

- Systematic planning of production activities to achieve the highest efficiency in production of goods/services
- To organize the production facilities like machines, men, etc., to achieve stated production Objectives with respect to quantity and quality time and cost
- Optimum scheduling of resources

- Coordinate with other departments relating to production to achieve regular balanced and uninterrupted production flow
- To conform to delivery commitments
- Materials planning and control
- To be able to make adjustments due to changes in demand and rush orders.

Parameters of Production Planning:

The various parameters of production planning may be explained as hereunder:

- **Materials:** Raw materials, finished parts and bought out components should be made available in required quantities and at required time to ensure the correct start and end for each operation resulting in uninterrupted production. The function includes the specification of materials (quality and quantity) delivery dates, variety reduction (standardization) procurement and make or buy decisions. In assembly line production material planning becomes very easy as there is no any frequent change in process and production takes place continuously.
- **Machines and equipment:** This function is related with the detailed analysis of available production facilities, equipment down time, maintenance policy procedure and schedules. Concerned with economy of jigs and fixtures and equipment availability. Thus, the duties include the analysis of facilities and making their availability with minimum down time because of breakdowns
- **Methods:** This function is concerned with the analysis of alternatives and selection of the best method with due consideration to constraints imposed. Developing specifications for processes is an important aspect of production planning and determination of sequence of operations. In assembly line all machines, equipments and man power are arranged in a line in the form of work station, therefore, it is the simplest in it.
- **Routing:** Routing means determination of most advantageous path to be followed from department to department and machine, till the raw material gets its final shape. Routing is related to considerations of layout, temporary storage of in process inventory and material handling.

  Routing in continuous production industries does not present any problem because of the product type of layout, where the machines are arranged according to the sequence of operations required to be performed on the components. As the production is made of standardized products, the number of operations and sequence of operations arc

standardized. The machines are arranged in sequence with automatic material handling systems. As the production is continuous and constant, routing becomes a routine and mechanical function. In automation routing is still simple and is governed automatically.

Advantages of Routing:

- Reduction in manufacturing costs;
- Improvement in quantity and quality of the output;
- Provides a basis for scheduling and loading.

- **Estimating:** Once the overall method and sequence of operations is fixed and process sheet for each operation is available, then the operations times are estimated. This function is carried out using extensive analysis of operations along with methods and routing and a standard time for operation are established using work measurement techniques.

- **Loading and scheduling:** Scheduling is concerned with preparation of machine loads and fixation of starting and completion dates for each of the operations. Machines have to be loaded according to their capability of performing the given task and according to their capacity. Thus the duties include:

  (a) Loading, the machines as per their capability and capacity.
  (b) Determining the start and completion times for each operation.
  (c) To coordinate with sales department regarding delivery schedules.

- **Dispatching:** This is the execution phase of planning. It is the process of setting production activities in motion through release of orders and instructions. It authorizes the start of production activities by releasing materials, components, tools, fixtures and instruction sheets to the operator.

  The activities involved are:

  - To assign definite work to definite machines, work centers and men
  - To issue required materials from stores
  - To issue jigs, fixtures and make them available at correct point of use
  - Release necessary work orders, time tickets, etc., to authorize timely start of operations

- To record start and finish time of each job on each machine or by each man.

Procedure for Production Planning

The process of production planning and control is based on a preset formulation. The plans are made for a specified time period keeping in view the stipulated costs and agreed policies. It is necessary to ensure that the plans are implemented properly. In planning, costs include the capital cost of the facility, assets and labor. The procedure followed in production planning is as follows:

1) **Demand predictions:** The production planning process begins with estimating or forecasting the demand among the consumers for the product or the service which is being offered.

    - Preparation of production budget: to compute the total cost of production.
    - Design the facility layout
    - Prescribe the types of machines and equipments to be used
    - Appropriation of production requirements: At the planning stage itself the appropriation of raw materials, men and machinery required is done. Specifics regarding their quality and quantity are decided.

2) **Schedules:** The schedules of production are drawn. Date by which a particular operation or production step should be completed is stipulated and reasonable allowances are made for any possible delays or errors.

    - The shortage or excess of the end product is ascertained in relation to efficiency of labor and equipment. According to the fluctuation in the demand for the product, necessary adjustments are made in capacity of machines and the number of labor.
    - Plans are drawn in case of a sudden surge in demand as in seasonal advantages of certain products. Cost of surplus inventory and stocks are taken account of.

3) **Rate of Production:** The rate and scale of production is set up. It is broken into realistic time periods and schedules. The stipulated or specified job needs to be finished by a particular date to start the next step.
    - In assembly line production, it is a great challenge to equalize the rate of production for each and every workstation. It is done through line balancing as explained earlier in this chapter. The main purpose is to reduce the line idle time so that line efficiency is the maximum.