MOHAMED SATHAK A.J. COLLEGE OF ENGINEERING
(Approved by AICTE, New Delhi and Affiliated to Anna University, Chennai)

ISO 9001:2015 Certified by IRQS NABCB QM 006

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE MATERIAL

IE 8693 - Production Planning and Control

IV YEAR - VIII SEMESTER

SYLLABUS (THEORY)			
Sub. Code	:IE 8693	**Branch / Year / Sem**	: MECH/IV/VIII
Sub.Name	:Production Planning and Control	**Staff Name**:Mr.K.K.VINOTHKUMAR	

OBJECTIVES:

- To understand the various components and functions of production planning and control such as workstudy, product planning, process planning, production scheduling, Inventory Control.
- To know the recent trends like manufacturing requirement Planning (MRP II) and Enterprise Resource Planning (ERP).

UNIT I INTRODUCTION 9

Objectives and benefits of planning and control-Functions of production control-Types of production job-batch and continuous-Product development and design-Marketing aspect - Functional aspects-Operational aspect-Durability and dependability aspect aesthetic aspect. Profit consideration-Standardization, Simplification & specialization- Break even analysis-Economics of a new design.

UNIT II WORK STUDY 9

Method study, basic procedure-Selection-Recording of process - Critical analysis, Development - Implementation - Micro motion and memo motion study – work measurement - Techniques of work measurement - Time study - Production study - Work sampling - Synthesis from standard data - Predetermined motion time standards.

UNIT III PRODUCT PLANNING AND PROCESS PLANNING 9

Product planning-Extending the original product information-Value analysis-Problems in lack of product planning-Process planning and routing-Pre requisite information needed for process planning- Steps in process planning-Quantity determination in batch production-Machine capacity, balancing- Analysis of process capabilities in a multi product system.

UNIT IV PRODUCTION SCHEDULING 9

Production Control Systems-Loading and scheduling-Master Scheduling-Scheduling rules-Gantt charts-Perpetual loading-Basic scheduling problems - Line of balance – Flow production scheduling- Batch production scheduling-Product sequencing – Production Control systems-Periodic batch control-Material requirement planning kanban – Dispatching-Progress reporting and expediting- Manufacturing lead time-Techniques for aligning completion times and due dates.

UNIT V INVENTORY CONTROL AND RECENT TRENDS IN 9

Inventory control-Purpose of holding stock-Effect of demand on inventories-Ordering procedures. Two bin system -Ordering cycle system-Determination of Economic order quantity and economic lot size- ABC analysis-Recorder procedure-Introduction to computer integrated production planning systems elements of JUST IN TIME SYSTEMS-Fundamentals of MRP II and ERP.

TOTAL: 45 PERIODS

OUTCOMES:

- Upon completion of this course, the students can able to prepare production planning and control activities such as work study, product planning, production scheduling, Inventory Control.
- They can plan manufacturing requirements manufacturing requirement Planning (MRP II) and Enterprise Resource Planning (ERP).

TEXT BOOKS:

1. Martand Telsang, “Industrial Engineering and Production Management”, First edition, S. Chand and b Company, 2000.
2. James.B.Dilworth,”Operations management – Design, Planning and Control for manufacturing and services” Mcgraw Hill International edition 1992.

REFERENCES:

1. Samson Eilon, “Elements of Production Planning and Control”, Universal Book Corpn.1984
2. Elwood S.Buffa, and Rakesh K.Sarin, “Modern Production / Operations Management”, 8th Edition, John Wiley and Sons, 2000.
3. Kanishka Bedi, “ Production and Operations management”, 2nd Edition, Oxford university press, 2007.
4. Melynk, Denzler, “ Operations management – A value driven approach” Irwin Mcgraw hill.

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COURSE OBJECTIVE

1. Understand the work study of production planning and control to produce a product.

2. Understand to prepare product planning sheet for new product or existing part production.

3. Identify different strategies employed in manufacturing and service industries to planproduction and control inventory.

4. To acquire knowledge to make MRP, MRP-II by using Modern Production planning softwarefor production of product with available resources.

Course Outcome

1. Understand the production planning processes to convert the raw material into finished product.

2. 2.Prepare the production planning activities chart for work study to reduce the production time.

3. Improve the market sale of existing product by changing the product planning

4. Select the suitable process planning for manufacturing of a product.5.Analyze the production schedule for the given product.

6.Analyze the inventory for a new product with help of latest software.

Prepared by

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HOD

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PRINCIPAL

Unit-I

INTRODUCTION

Introduction of Production Planning and Control Functions

All of the four basic phases of control of manufacture are easily identified in production planning and control. The plan for the processing of materials through the plant is established by the functions of process planning, loading, and scheduling. The function of dispatching puts the plan into effect; that is, operations are started in accordance with the plant. Actual performance is then compared to the planned performance, and, when required, corrective action is taken. In some instances re-planning is necessary to ensure the effective utilization of the manufacturing facilities and personnel.

Let us examine more closely each of these functions.

ProcessPlanning (Routing)

The determination of where each operation on a component part, subassembly, or assembly is to be performed results in a route for the movement of a manufacturing lot through the factory. Prior determination of these routes is the job of the manufacturing engineering function.

Loading

Once the route has been established, the work required can be loaded against the selected machine or workstation. The total time required to perform the operation is computed by multiplying the unit operation times given on the standard process sheet by the number of parts to be processed. This total time is then added to the work already planned for the workstation. This is the function of loading, and it results in a tabulated list or chart showing the planned utilization of the machines or workstations in the plant.

Scheduling

Scheduling is the last of the planning functions. It determines when an operation is to be performed, or when work is to be completed; the difference lies in the detail of the scheduling procedure. In a centralized control situation - where all process planning, loading, and scheduling for the plant are done in a central office- the details of the schedule may specify the starting and finishing time for an operation. On the other hand, the central schedule may simply give a completion time for the work in a given department.

Combining Functions

While it is easy to define “where” as process planning, “how much work” as loading, and “when as scheduling, in actual operations these three functions are often combined and performed concurrently. How far in advance routes, loads, and schedules should be established always presents an interesting problem. Obviously, it is desirable that a minimum of changes be made after schedules are established. This objective can be approached if the amount of work scheduled for the factory or department is equal to or slightly greater than the manufacturing cycle. For optimum control, it should never be less than the manufacturing cycle.

Dispatching

Authorizing the start of an operation on the shop floor is the function of dispatching. This function may be centralized or decentralized. Again using our machine-shop example, the departmental dispatcher would authorize the start of each of the three machine operations –three dispatch actions based on the foreman's routing and scheduling of the work through his department. This is decentralized dispatching.

Reporting or Follow – up

The manufacturing activity of a plant is said to be "in control" when the actual performanceis within the objectives of the planned performance. When jobs are started and completed on schedule, there should be very little, if any, concern about the meeting of commitments. Optimum operation of the plant, however, is attained only if the original planhas been carefully prepared to utilize the manufacturing facilities fully and effectively.

Corrective Action

This is the keystone of any production planning and control activity. A plant in which all manufacturing activity runs on schedule in all probability is not being scheduled to its optimum productive capacity. With an optimum schedule, manufacturing delays are the rule, not the exception.

Re-planning

Re-planning is not corrective action. Re-planning revise routes, loads, and schedules; a new plan is developed. In manufacturing this is often required. Changes in market conditions, manufacturing methods, or many other factors affecting the plant will often indicate that a new manufacturing plan is needed.

Objectives and benefits Production Planning and Control

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. Specific objectives of production planning and control are to establish routes and schedules for 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.

Function of production control

Function of production control are

1. Utilizes resources effectively.
2. Makes flow of production steady.
3. Estimates production resources.
4. Maintains necessary stock levels.
5. Coordinates departmental activities.
6. Minimizes wastage of resources.
7. Improves labor efficiency.
8. Helps to face competition.
9. Provides better work environment.
10. Facilitates quality improvement.
11. Customer satisfaction.
12. Reduces production costs.

All of the four basic phases of control of manufacture are easily identified in production planning and control. The plan for the processing of materials through the plant is established by the functions of process planning, loading, and scheduling. The function of dispatching puts the plan into effect; that is, operations are started in accordance with the plant. Actual performance is then compared to the planned performance, and, when required, corrective action is taken. In some instances re-planning is necessary to ensure theeffective utilization of the manufacturing facilities and personnel. Let us examine more closely each of these functions.

TYPES OF PRODUCTION SYSTEM

There are eight types of production which may be classified in three or four broad groups according to the quantities of production involved [Samuel Eilon]. They are shown in Figure in terms of product variety and production volume—the figure is self explanatory.

1. **Job Shop Production system which has the following features :**
   (a) A small number of items produced only once,
   (b) A small number of items produced intermittently when the need is
   felt, (*c*) A small number of items produced periodically at known timeinterval.

2. **Batch Production which has the following characteristics :**

(a) A batch of items produced only once,

(b) A batch of items produced at irregular intervals when a need is felt,

(c) A batch of items produced periodically at known intervals to satisfy the continuousdemand.

3. **Continuous Production which consists of**

(a) Mass production

(b) Flow production

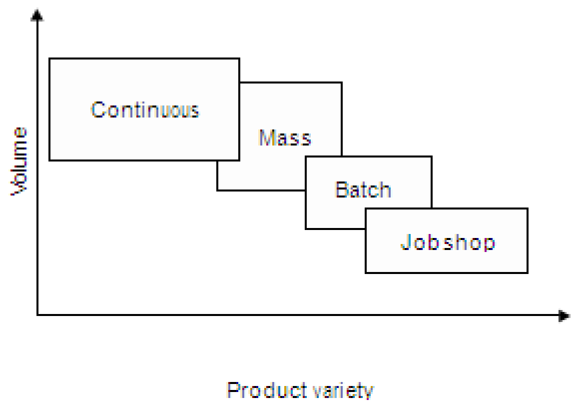


Figure 1.2. Different Types of Production Systems

Job Production

This is the oldest method of production on a very small scale. It is also popularly known as 'job-shop or Unit' production. With this method individual requirements of consumers can be met. Each job order stands alone and may not be repeated. Some of the **examples** include manufacturing of aircrafts, ships, space vehicle, bridge and dam construction, ship building, boilers, turbines, machine tools, things of artistic nature, die work, etc. Some of the features of this system are as follows**:**

- This system has a lot of flexibility of operation, and hence general purposemachines are required.
- Generally no automation is used in this system, but computer-aided-design (CAD) isused.
- It deals with 'low volume and large variety' production. It can cater to specificcustomer order, or job of one kind at a time.
- It is known for rapid value addition.

Advantages

- Low risk of loss to the factory adopting this type of production. Due to flexibility, there is no chance of failure of factory due to reduction in demand. It can always get one or the other job orders to keep it going.
- Requires less money and is easy to start.
- Less or no management problem because of very small work force.

Batch and continuous

productionBatch Production

The *batch production system* is generally adopted in medium size enterprises. Batch production is a stage in between **mass production** and **job-shop** production. As in this system,two or more than two types of products are manufactured in lots or batches at regular interval, which justifies its name the ‘batch production system’.

It has the following features:

- A batch production turns into flow production when the rest period vanishes. In flowproduc- tion, the processing of materials is continuous and progressive.
- Batch production is bigger in scale than job production, but smaller than that of massproduc- tion.
- Material handling may be automated by robots as in case of CNC machining centers.
- A medium size lots (5 to 50) of same items is produced in this system. Lot may beproduced once in a while or on regular interval generally to meet the continuous customer demands.
- Plant capacity generally is higher than demand.

Advantages

- It is flexible in the sense that it can go from one job to another with almost zero cost.It needs general purpose machine having high production rate.
- If demand for one product decreases then production rate for another product may beincreased, thus the risk of loss is very less.
- Most suitable for computer-aided-manufacturing (CAM).

Disadvantages

- As the raw materials to be purchased are in smaller quantity than in case of massproduction, the benefits of discount due to large lot purchasing is not possible.
- It needs specially designed jigs and fixtures.

Continuous Production

In this, the production activity continues for 24 hours or on three shifts a day basis. A steel plant, for **example**, belongs to this type. It is impossible to stop the production process on a short notice without causing a great damage to its blast furnace and related equipment. Other examples include bottling plant, soft drink industry, fertilizer plant, power plant, etc). *Mass production* and *Flow production* belong to continuous type only. They are explained below:

Mass production: In this type, a large number of identical items is produced, however, the equip- ment need not be designed to produce only this type of items. Both plant and equipment are flexible enough to deal with other products needing the same production processes. For **example,** a highly mechanized press shop that can be utilized to produce different types of components or products of steel metal without the need of major changes.

***Flow production*:** In this type, the plant, its equipment, and layout have been chiefly designed to produce a particular type of product. Flexibility is limited to minor modifications in layout or design of models. Some famous **examples** are automobiles, engines, house-hold machinery, chemical plants, etc. If the management decides to switch over to a different type of product, it will result in extensive change in tooling, layout, and equipment.

Continuous production, in general, has the following *features*:

- It is very highly automated (process automation), and highly capital intensive. Items move from one stage to another automatically in a continuous manner.
- It has a fixed or hard automation which means there is very less or no flexibility at all. Layout of the plant is such that it can be used for only one type of product. Each machine in the system is assigned a definite nature of work.
- To avoid problem of material handling, use of cranes, conveyors etc. are made.
- Work-in-process (WIP) inventory in this system is zero.

Advantages

- It gives better quality, large volume but less variety of products.
- Wastage is minimum.
- As the raw materials are purchased on a large scale, higher margin of profit can bemade on purchase.
- Only a few skilled, and many semi-skilled workers are required. This reduces thelabor cost substantially.

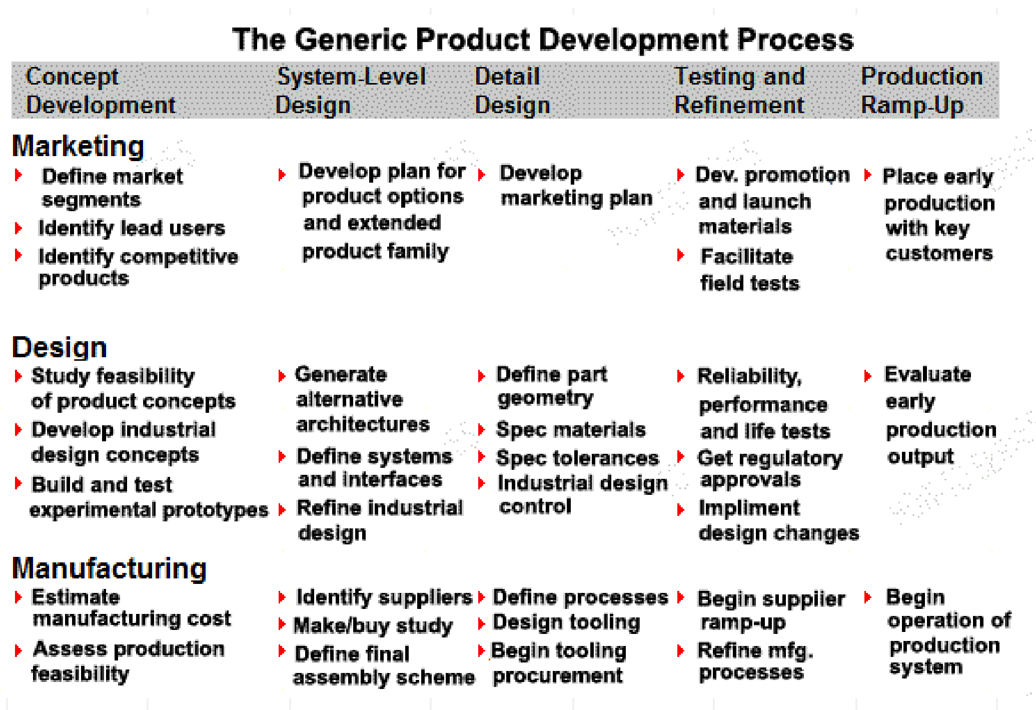
Disadvantages

- During the period of less demand, heavy losses on invested capital may take place.
- Because all the machines are dedicated and special purpose type, the system is notchange- able to other type of production.
- Most of the workers handle only a particular operation repetitively, which canmake them feel monotonous.
- As this type of production is on the large scale, it cannot fulfill individual taste.

Product Development and design

Product development is the process of creating a new product to be sold by a business or enterprise to its customers. In the document title, Design refers to those activities involved in creating the styling, look and feel of the product, deciding on the product's mechanical architecture, selecting materials and processes, and engineering the various components necessary to make the product work. Development refers collectively to the entire process of identifying a market opportunity, creating a product to appeal to the identified market, and finally, testing, modifying and refining the product until it is ready for production. A product can be any item from a book, musical composition, or information service, to an engineered product such as a computer, hair dryer, or washing machine. This document is focused on the process of developing discrete engineered products, rather than works of art or informational products.

The process of developing new products varies between companies, and even between products within the same company. Regardless of organizational differences, a good new product is the result a methodical development effort with well defined product specifications and project goals. A development project for a market-pull product is generally organized along the lines shown in Figure

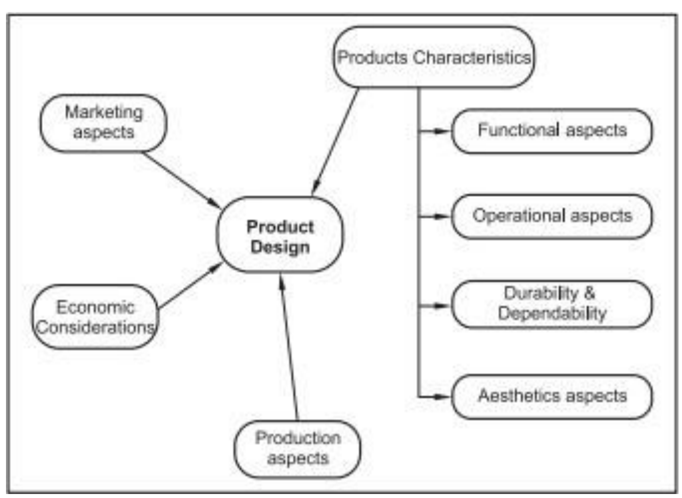


The Generic Product Development Process

	Concept Development	System-Level Design	Detail Design	Testing and Refinement	Production Ramp-Up
Marketing	Define market segments Identify lead users Identify competitive products	Develop plan for product options and extended product family	Develop marketing plan	Dev. promotion and launch materials Facilitate field tests	Place early production with key customers
Design	Study feasibility of product concepts Develop industrial design concepts Build and test experimental prototypes	Generate alternative architectures Define systems and interfaces Refine industrial design	Define part geometry Spec materials Spec tolerances Industrial design control	Reliability, performance and life tests Get regulatory approvals Impliment design changes	Evaluate early production output
Manufacturing	Estimate manufacturing cost Assess production feasibility	Identify suppliers Make/buy study Define final assembly scheme	Define processes Design tooling Begin tooling procurement	Begin supplier ramp-up Refine mfg. processes	Begin operation of production system

Marketing Aspects

It is very important to know whether the planned product can satisfy a demand in the market and that it would be acceptable by customers. It there is no potential market, then it is wasteful exercise to design and manufacture the product. Therefore before going for the product design and other activities, the marketability of the product should be carefully examined.



The demand for the existing product can be easily estimated. But if the product is entirely new to the market, a detailed market survey is to be carried out to estimate the demand for the product.

Functional aspects Functional aspects

When the marketing possibilities have been explored, the functional scope of the product has to be carefully analysed and properly defined. The functional objectives are to be fixed with respect to the product as given here.

1. What are the functions the product is expected to perform?
2. Whether single function or multiple functions are to be incorporated in the product?
3. Cost considerations due to offering multiple functions.

Operational aspects

Once the functional aspects of the proposed product are determined, then operational aspects of the product has to be carefully analysed and properly defined.

The product produced should be easy to handle and simple to operate at the customersend.

The product may be used in different operational conditions and the customers vary withrespect to skill and knowledge.

Durability and dependability aspects:

Durability and dependability are the two important aspects that often determine quality and reliability of the product.

Durability can be defined as active life of a product under given working conditions.

Reliability is probability that a particular product would perform satisfactorily for the period intended under a given operating conditions.

Dependability is the capability of the product to function when called upon to do the job.

Aesthetic aspect

Aesthetic aspect refers to the "external look good" aspect of the product. It makes the product attractive to the customers and creates good impression about the product. For many consumer goods like automobiles, house hold equipment etc. aesthetics is the dominant factor in creating demand for the product.

The following factors are usually utilised by the designer to bring out aesthetecharacteristics:

(a) Use of special materials
(b) Use of colours and colour combinations
(c) Surface finish and textures
(d) Shape by contours

PROFIT CONSIDERATION, STANDARDIZATION, SIMPLIFICATION

PROFIT CONSIDERATION

Profit making is the ultimate goal for any organization. So a thorough analysis of various expenditures incurred for manufacturing with reasonable profit margin is necessary for the survival of companies. If an organization wants to increase the total profit percentage, then it has to follow any one of the methods described below

(a) by increasing profit margin

(b) by implementing effective marketing strategy

(c) by reducing production cost

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

Advantages of Standardization

All the sections of company will be benefited from standardization as mentioned below.

Benefits to Design Department

1. Fewer specifications, drawings and part list have to prepared and issued.
2. More time is available to develop new design or to improve established design.
3. Better resource allocation.
4. Less qualified personnel can handle routine design work.

Benefits to Manufacturing Department

1. Lower unit cost.
2. Better quality products.
3. Better methods and tooling.
4. Increased interchangeability of parts.
5. Better utilization of manpower and equipment.
6. Accurate delivery dates.
7. Better services of production control, stock control, purchasing, etc.
8. More effective training.

Benefits to Marketing Department

1. Better quality products of proven design at reasonable cost leads to greater salesvolume.
2. Increased margin of profit.
3. Better product delivery.

4. Easy availability of sales part.
5. Less sales pressure of after-sales services.

Benefits to Production Planning Department

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

Benefits to Production Control Department

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

Benefits to Purchase and Stock Control Department

1. Holding of stock of standard items leads to less paper work and fewer requisitionsand orders.
2. Storage and part location can be improved.
3. Newer techniques can be used for better control of stocks.
4. Because of large purchase quantities involved, favourable purchase contracts can bemade.

Benefits to Quality Control Department

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

Other Benefits

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

Disadvantages of Standardization

Following are the disadvantages of standardization:

1. Reduction in choice because of reduced variety and consequently loss of businessor customer.
2. Standard once set, resist change and thus standardization may become an obstacleto progress.
3. It tends to favour only large companies.
4. It becomes very difficult to introduce new models because of less flexible production facilities and due to high cost of specialised production equipment.

SIMPLIFICATION

The concept of simplification is closely related to standardization. Simplification is the processof reducing the variety of products manufactured. Simplification is concerned with the reduction of product range, assemblies, parts, materials and design.

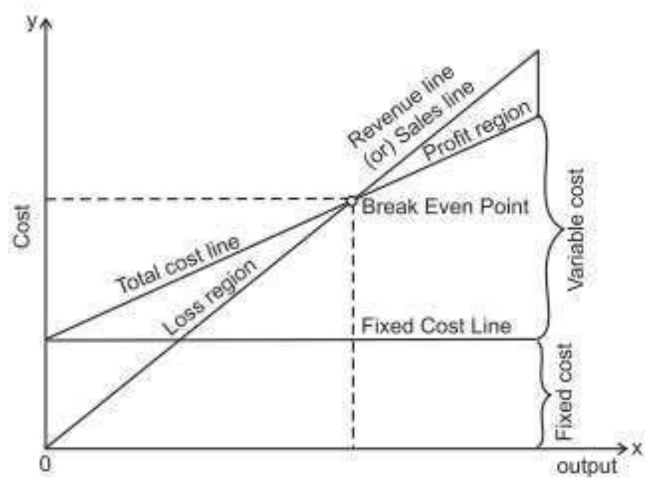
Advantages of Simplification

Following are the advantages of simplification:

1. Simplification involves fewer, parts, varieties and changes in products; thisreduces manufacturing operations and risk of obsolescence.
2. Simplification reduces variety, volume of remaining products may be increased.
3. Simplification provides quick delivery and better after-sales services.
4. Simplification reduces inventory and thus results in better inventory control.
5. Simplification lowers the production costs.
6. Simplification reduces price of a product.
7. Simplification improves product quality

Break-Even Analysis

The main objective of break-even analysis is to find the cut-off production volume from wherea firm will make profit



It is also called as CVP (Cost, Volume, and Profit) analysis. Break even analysis is used to find the level at which the total cost and total revenue becomes equal. It is foolishness on thepart of management to run a business without break even analysis

Significance of BEA

1. It gives, the minimum number of units to be produced so that there is no loss.

2. It indicates when the profit is attained.

3. To fix the bonus for employees and other wage calculations, this analysis is used.

The break even point can be obtained by graph. In this graph when totalsales line intersects the total cost line, the BEP is obtained.

B.E.P can be obtained in terms of

(a) Number of units (How much minimum number of units should be produced to avoid loss)

(b) Sales Volume (or) Total Revenue (How much sales volume should be achieved to avoid loss)

(c) % of estimated capacity (What is the % of estimated capacity should be attained to avoidloss).

Break Even Point (BEP)

'BEP' is the production/sales level at which the total revenue equals total expenses. It is the point at which a product, project or a business becomes commercially viable. Operating beyond the BEP results in profits and operating below the BEP results in losses. Also BEP is a measure of how long it takes to recover ones investments. Many companies prefer a BEP of 18 months or less.

Now if P = Salting price (Rs./unit)

F = Fixed cost (Rs.)

V = Variable cost (Rs./unit)

Q = Production volume (units)

ECONOMICS OF A NEW DESIGN

In order to survive in the competitive atmosphere of industrial world, a new product (or) modification of existing product is essential. During the launch of a new model (or) design, a eful analysis of the economics of the proposed project has to be done. The reason forintroducing a new model to the market is

1. To increase the profit of the company.

2. To avoid decrease in sales of an existing product.

Samuel Eilon's mathematical model of profit-volume analysis is the useful tool to determine whether the additional investment (I) of monetary units (due to process change, design change, material change) is desirable or not.

$P1$ is the profit obtained before investment

$P2$ is the profit obtained after investment.

By comparing $P1$ & $P2$, the decision is made.

Let, $F \rightarrow$ Fixed cost

$I \rightarrow$ Additional investment made$P \rightarrow$ Profit

$N \rightarrow$ Quantity sold.

We know that the slope of break even chartφ = (Profit + Fixed cost)/ Quantity sold

Before Investment

The slope of break even chart is$\varphi 1 = (P1 + F)/N1$

$\therefore P1 = \varphi 1\ N1 - F$

After Investment

The slope of break even chart is$\varphi 2 = (P2 + F + I)/N2$

$\therefore P2 = \varphi 2\ N2 - F - I$

UNIT II WORKSTUDY

WORK STUDY

- First technique applied for increasing productivity.
- Considered as a valuable tool in increasing productivity.

Definition:

Work study is a generic term for the techniques of method study and work measurement. These techniques are used in the examination of human work in all its contexts. They lead systematically to the investigation of all the factors which affect the efficiency and economy at the work place in order to affect improvement.

&2.2 METHOD STUDY AND BASIC PROCEDURE

Method study is the technique of systematic recording and critical examination of existing and proposed ways of doing work and developing an easier and economical method.

Objectives of Method Study

1. Improvement of manufacturing processes and procedures.
2. Improvement of working conditions.
3. Improvement of plant layout and work place layout.
4. Reducing the human effort and fatigue.
5. Reducing material handling
6. Improvement of plant and equipment design.
7. Improvement in the utility of material, machines and manpower.
8. Standardisation of method.
9. Improvement in safety standard.

BASIC PROCEDURE FOR METHOD STUDY

The basic procedure for conducting method study is as follows:

1. Select the work to be studied.
2. Record all facts about the method by direct observation.
3. Examine the above facts critically.
4. Develop the most efficient and economic method.
5. Define the new method.
6. Install the new method
7. Maintain the new method by regular checking.

Selection and Recording

SELECTION

While selecting a job for doing method study, the following factors are considered:

(a) Economical factors.

(b) Human factors.

(c) Technical factors.

(a) Economical Factors

The money saved as a result of method study should be sufficiently more. Then only the studywill be worthwhile. Based on the economical factors, generally the following jobs are selected.

(a) Operations having bottlenecks (which holds up other productionactivities).

(b) Operations done repetitively.

(c) Operations having a great amount of manual work.

(d) Operations where materials are moved for a long distance.

(b) Human Factors

The method study will be successful only with the co-operation of all people concerned *viz.*, workers,

supervisor, trade unions etc.

Workers may resist method study due to

1. The fear of unemployment.
2. The fear of reduction in wages.
3. The fear of increased work load.

then if they do not accept method study, the study should be postponed.

(c) Technical Factors

To improve the method of work all the technical details about the job should be available. Every machine tool will have its own capacity. Beyond this, it cannot be improved.

For example, a work

study man feels that speed of the machine tool may be increased and HSS tool may be used. But the capacity of the machine may not permit increased speed. In this case, the suggestion of the work study man cannot be implemented. These types of technical factors should be considered.

RECORDING OF PROCESS

All the details about the existing method are recorded. This is done by directly observingthe work.

Symbols are used to represent the activities like operation, inspection, transport, storage anddelay.

Different charts and diagrams are used in recording. They are:

1. Operation process chart: All the operations and inspections are recorded.
2. Flow process chart
   - *(a)* Man type All the activities of man are recorded
   - *(b)* Material type All the activities of the material are recorded
   - *(c)* Equipment type All the activities of equipment or machine are recorded.
3. Two-handed process chart: Motions of both lands of worker areRight hand-Left hand chart recorded independently.
4. Multiple activity chart: Activities of a group of workers doing a single job or theactivities of a single worker operating a number of machines are recorded.
5. Flow diagram: This is drawn to suitable scale. Path of flow of material in the shop isrecorded.
6. String diagram: The movements of workers are recorded using a string in a diagramdrawn to scale.

3. Examine

Critical examination is done by questioning technique. This step comes after themethod is recorded by suitable charts and diagrams.

The individual activity is examined by putting a number of questions.

The following factors are questioned

1. Purpose – To eliminate the activity, if possible.
2. Place – To combine or re-arrange the activities.
3. Sequence – -do-
4. Person – -do-
5. Means – To simplify the

activity.The following sequence of questions is used:

1. Purpose – What is actually done?Why is it done?
   What else could be done?What should be done?
2. Place – Where is it being done?Why is it done there?
   Where else could it be done?Where should it be done?

3. Sequence – When is it done?Why is it done then? When could it be done? When should it be done?
4. Person – Who is doing it? Why does that person do it? Who else could do it? Who should do it?
5. Means – How is it done?Why is it done that way? How else could it be done?How should it be done?

By doing this questioning

- Unwanted activities can be eliminated
- Number of activities can be combined or re-arranged
- Method can be simplified.

All these will reduce production time.

4. Develop

The answer to the questions given below will result in the development of a better method.

1. Purpose – What should be done?
2. Place – Where should it be done?
3. Sequence – When should it be done?
4. Person – Who should do it?
5. Means – How should it be done?

5. Define

Once a complete study of a job has been made and a new method is developed, it is necessary to obtain the approval of the management before installing it. The work study man should prepare a report giving details of the existing and proposed methods. He should give his reasons for the changes suggested. The report should show

(a) Brief description of the old method.

(b) Brief description of the new method.

(c) Reasons for change.

(d) Advantages and limitations of the new method.

(e) Savings expected in material, labour and overheads.
(f) Tools and equipment required for the new method.
(g) The cost of installing the new method including.
1. Cost of new tools and equipment.
2. Cost of re-layout of the shop.
3. Cost of training the workers in the new method.
4. Cost of improving the working conditions.

Written standard practice: Before installing the new method, an operator's instructions sheet called written standard practice is prepared. It serves the following purposes:

1. It records the improved method for future reference in as much detail as may be necessary.
2. It is used to explain the new method to the management foreman and operators.
3. It gives the details of changes required in the layout of machine and work places.
4. It is used as an aid to training or retraining operators.
5. It forms the basis for time studies.

The written standard practice will contain the following information:

(a) Tools and equipment to be used in the new method.
(b) General operating conditions.
(c) Description of the new method in detail.
(d) Diagram of the workplace layout and sketches of special tools, jigs or fixturesrequired.

6. Install

This step is the most difficult stage in method study. Here the active support of both management and trade union is required. Here the work study man requires skill in getting along with other people and winning their trust. Install stage consists of

(a) Gaining acceptance of the change by supervisor.
(b) Getting approval of management.
(c) Gaining the acceptance of change by workers and trade unions.
(d) Giving training to operators in the new method.
(e) To be in close contact with the progress of the job until it is satisfactorily executed.

7. Maintain

The work study man must see that the new method introduced is followed. The workers after some time may slip back to the old methods. This should not be allowed. The new method may have defects. There may be difficulties also. This should be rectified in time by the work study man. Periodical review is made. The reactions and suggestions from workers and supervisors are noted. This may lead to further improvement. The differences between the new written standard practice and the actual practice are found out. Reasons for variations are analysed. Changes due to valid reasons are accepted. The instructions are suitably modified.

CHARTS AND DIAGRAMS USED IN METHOD STUDY (TOOLS ANDTECHNIQUES)

As explained earlier, the following charts and diagrams are used in method study.

1. Operation process chart (or) Outline process chart.
2. Flow process chart.
   (a) Material type
   (b) Operator type
   (c) Equipment type
3. Two-handed process chart. (or) Left hand-Right hand chart
4. Multiple activity chart.
5. Flow diagram.
6. String diagram.

Process Chart Symbols

The recording of the facts about the job in a process chart is done by using standardsymbols. Using of symbols in recording the activities is much easier than writing down the facts about the job. Symbols are very convenient and widely understood type of short hand. They save a lot of writing and indicate clearly what is happening.

1. Operation

A large circle indicates operation. An operation takes place when there is a change inphysical or chemical characteristics of an object. An assembly or disassembly is also an operation.

When information is given or received or when planning or calculating takes place it is alsocalled operation.

Example

Reducing the diameter of an object in a lathe. Hardening the surface of an object by heat treatment.

2. Inspection

A square indicates inspection. Inspection is checking an object for its quality, quantity or identifications.

Example 1.2

Checking the diameter of a rod. Counting the number of products produced.

3. Transport

An arrow indicates transport. This refers to the movement of an object or operator or equipment from one place to another. When the movement takes place during an operation, it isnot called transport.

Example

Moving the material by a trolley

Operator going to the stores to get some tool.

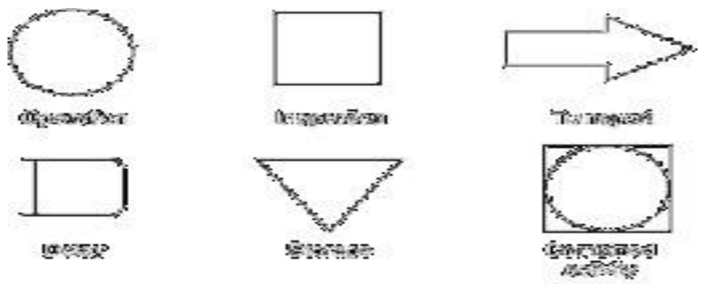


Fig. 1.1: Process chart symbols

Delay or temporary storage

A large capital letter D indicates delay. This is also called as temporary storage. Delay occurswhen an object or operator is waiting for the next activity.

Example 1.4

An operator waiting to get a tool in the stores. Work pieces stocked near the machine beforethe next operation.

10 Process Planning and Cost Estimation

4. Permanent storage

An equilateral triangle standing on its vertex represents storage. Storage takes place when anobject is stored and protected against unauthorized removal.

Example 1.5

Raw material in the store room.

5. Combined activity

When two activities take place at the same time or done by the same operator or at the sameplace, the two symbols of activities are combined.

Example 1.6

Reading and recording a pressure gauge. Here a circle inside a square represents the combined activity of operation and inspection.

Operation Process Chart

An operation process chart is a graphic representation of the sequence of all operations and inspections taking place in a process. It is also known as outline process chart. It gives a bird‘seye view of the overall activities. Entry points of all material are noted in the chart.

An example of operation process chart is shown in the figure 1.2. Here the process ofmanufacture of electric motor is shown.

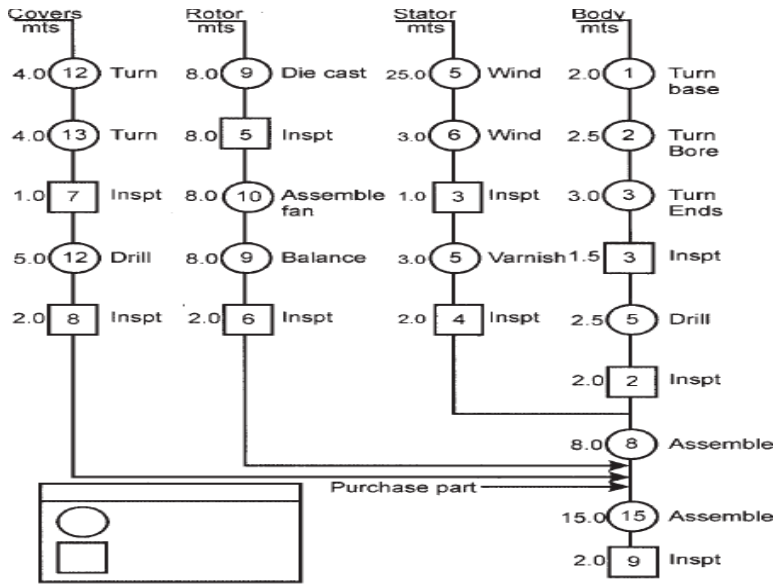


Fig. 1.2: Operation process chart

The conventions followed in preparing the chart are

1. Write title at the top of the chart.
2. Begin the chart from the right hand side top corner.
3. Represent the main component at the right extreme.
4. Represent the sequence of operations and inspections by their symbols. Connectthem By vertical flow lines.
5. Record the brief description of the activity tothe right side of the symbols.
6. Note down the time for each activity to the left of the symbol.
7. Number all operations in one serial order. Start from the right hand top (fromnumber
8. Similarly number all inspections in another serial order (starting from 1).
9. Continue numbering, till the entry of the second component.
10. Show the entry of purchased parts by horizontal lines.

Flow Process Chart

A flow process chart is a graphical representation of the sequence of all the activities (operation, inspection, transport, delay and storage) taking place in a process. Process chart symbols are used here to represent the activities. There are three types of flow process charts.

are

1. Man type flow process chart

This flow process chart records what the worker does.

2. Material type flow process chart

This flow process chart records how the material is handled or treated.

3. Equipment type flow process chart

This flow process chart records how the equipment or machine is used.

Example 1.7

The activities of a stenographer in preparation of a letter are recorded in the operatortype flow process chart shown in figure 1.3.

Chart No.	: 001	Date :	
Job	: Typing A letter	Charted by:	....
Chart begins	: Steno in her seat	Chart ends-putting the typed letter in the way	
Method	: Present/Proposed		

Sl. No.	Description of the activities	Distance	Time in Sec.	Symbols ○ □ ⇒ D ∇	Remarks
1.	Steno in her seat	-	-		
2.	Hears the bell	-	3		
3.	Goes to manager's room	6m	10		
4.	Takes down dictation	-	120		
5.	Returns to her seat	6m	10		
6.	Prepares typewriter	-	15		
7.	Types the letter	-	150		
8.	Checks the matter	-	40		
9.	Goes to manager's room	6m	10		
10.	Waits till the manager signs	-	20		
11.	Returns to her seat	6m	10		
12.	Types envelope	-	20		
13.	Puts the letter inside envelope	-	5		
14.	Puts the envelope in dispatch tray	-	5		

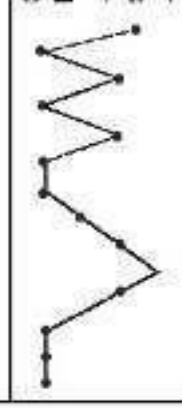


Fig. 1.3: Flow process chart—operator type

The chart records the activities of the steno. Here, the manager calls the steno and dictates a letter. The steno takes notes of the letter, types it, gets the signature of the manager and sends it for dispatching. These activities are shown in the chart. This is operator type flow process chart.
Considering the message in the letter as material, we can prepare the material type flow process chart.

General guidelines for making a flow process chart

1. The details must be obtained by direct observation—charts must not be based onmemory.
2. All the facts must be correctly recorded.
3. No assumptions should be made.
4. Make it easy for future reference.
5. All charts must have the following details:
   (a) Name of the product, material or equipment that is observed.
   (b) Starting point and ending point.
   (c) The location where the activities take place.
   (d) The chart reference number, sheet number and number of total sheets.
   (e) Key to the symbols used must be stated.

Two-Handed Process Chart (or) Right Hand, Left Hand Chart

- It is the process chart in which the activities of two hands of the operator arerecorded.
- It shows whether the two hands of the operator are idle or moving in relation toone another, in a timescale.
- It is generally used for repetitive operations.

Operation: Represents the activities grasp, position, use, release etc. of a tool,component or material.

Transport: Represents the movement of the hand or limb to or from the work or atool or material.

Delay: Refers to the time when the hand or limb is idle.

Storage (Hold): The term ‗hold' is used here instead of storage. This refers to thetime when the work is held by hand.

The activity ‗inspection' by hand is considered as an operation. Hence, the symbol forinspection is not used in this chart.

Two-handed process chart can be used for assembly, machining and clerical jobs.

General guidelines for preparing the chart

1. Provide all information about the job in the chart.
2. Study the operation cycle a few times before starting to record.
3. Record one hand at a time.
4. First record the activities of the hand which starts the work first.
5. Do not combine the different activities like operations, transport etc.

Example

Example of a two-handed process chart is shown in figure 1.4. Here the assembly of anut and washer over a bolt is recorded.

The work place layout is shown in the right hand corner. The activities of left hand arerecorded at left half of the chart. The activities of the right hand are recorded at the right half of the chart.

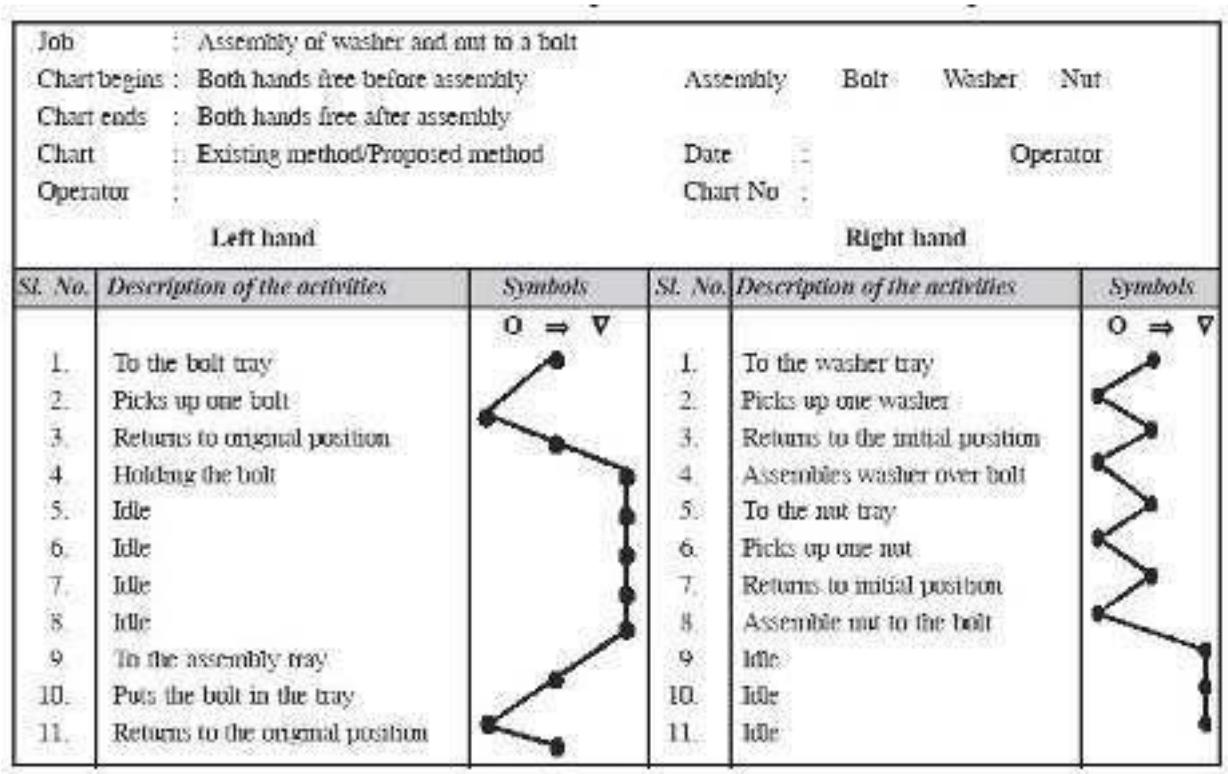


Fig. 1.4: Two-handed process chart

The horizontal lines represent the time scale. Activities of left hand and right handshown in the same line occur at the same moment.

Summary of the number of each activity can be tabulated at the bottom of the chart. The chart is first drawn for the existing method. This chart is analysed and if it is found that one hand is over loaded than the other, modification are done in the layout of the workplaceor in the sequence of activities. Then a new chart is made for the proposed cycle.

Man-Machine Chart

A man-machine chart is a chart in which the activities of more than one worker or machine are recorded. Activities are recorded on a common time scale to show the inter-relationship. It is also known as multiple activity chart.

It is used when a worker operates a number of machines at a time. It is also used when a number of workers jointly do a job.

Activities of workersor machines are recorded in separate vertical columns (bars) with ahorizontal time scale.

The chart shows the idle time of the worker or machine during the process.By carefully analyzing the chart, we can rearrange the activities. Work load is evenly distributed among the workers or machines by this the idle time of worker or machine is reduced. Multiple activity chart is very useful in planning team work in production or maintenance. Using the chart we can find out the correct number of machines that a worker can operate at a time. We can also find out the exact number of workers needed to do a job jointly.

To record the time, ordinary wrist watch or stop watch is used. High accuracy is not needed. Man-machine chart is a type of multiple activity chart. Here, the activities of a number of machines are recorded.

An example of man-machine chart is shown in figure 1.5. Here one operator two semi-automatic machines simultaneously. The activities of the operator is recorded in a separate vertical column. The activities of the two machines are recorded in two separate vertical columns. The different activities like loading, machining and unloading are represented by different symbols. Blank space shows the idle time.

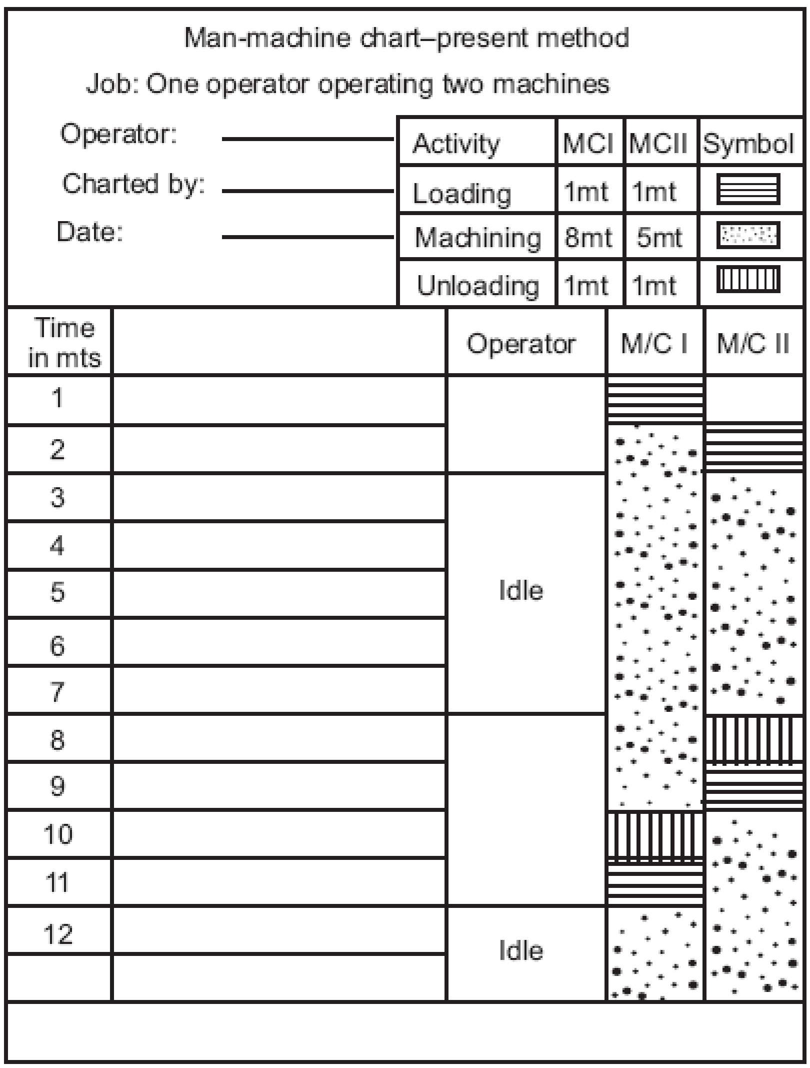


Fig. 1.5: Man-machine chart

Flow Diagram

In any production shop, repair shop or any other department, there are movements ofmen and material from one place to another. Process charts indicate the sequence of activities. They do not show the frequent movements of men and material. If these movement are minimized, a lot of savings can be achieved in cost and effort. If the path of movement of material is not frequent and simple, a flow diagram is used for recording the movement.

A flow diagram is a diagram which is drawn to scale. The relative position of machineries, gang ways, material handling equipment etc. are drawn first. Then the path followed by men or material is marked on the diagram. Different movements can be marked in different colours. Process symbols are added to the diagram to identify the different activities at different work centres.

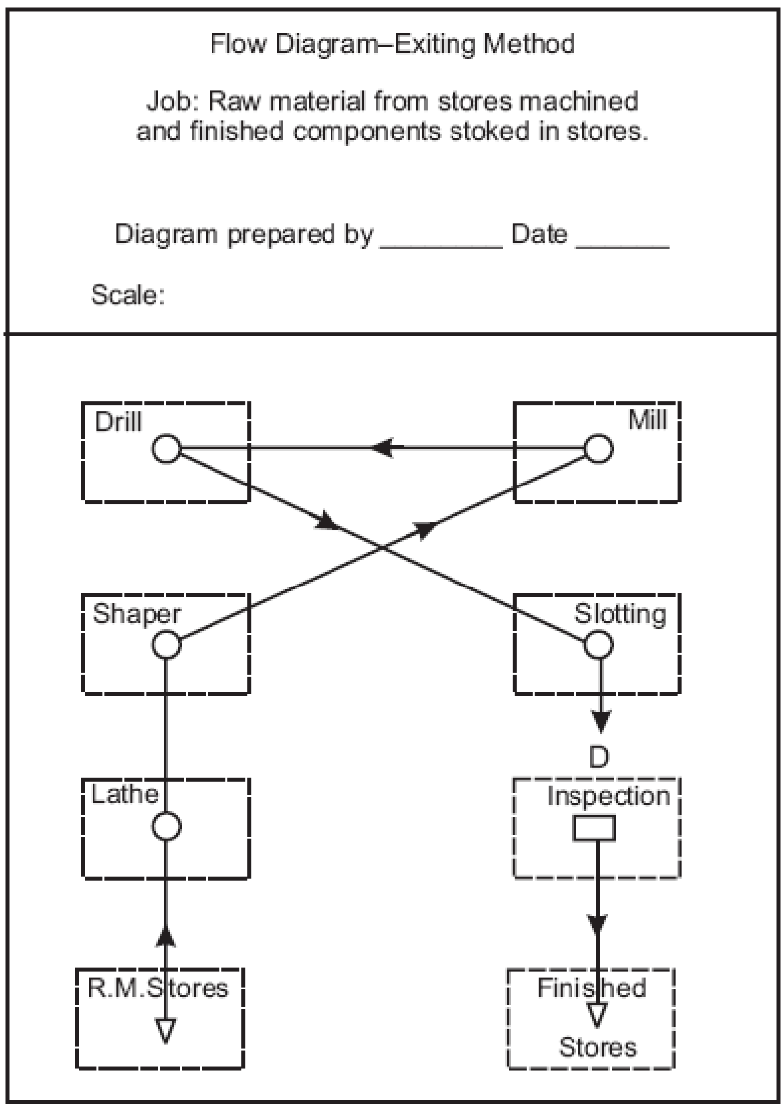


Fig. 1.6: *Flow diagram*

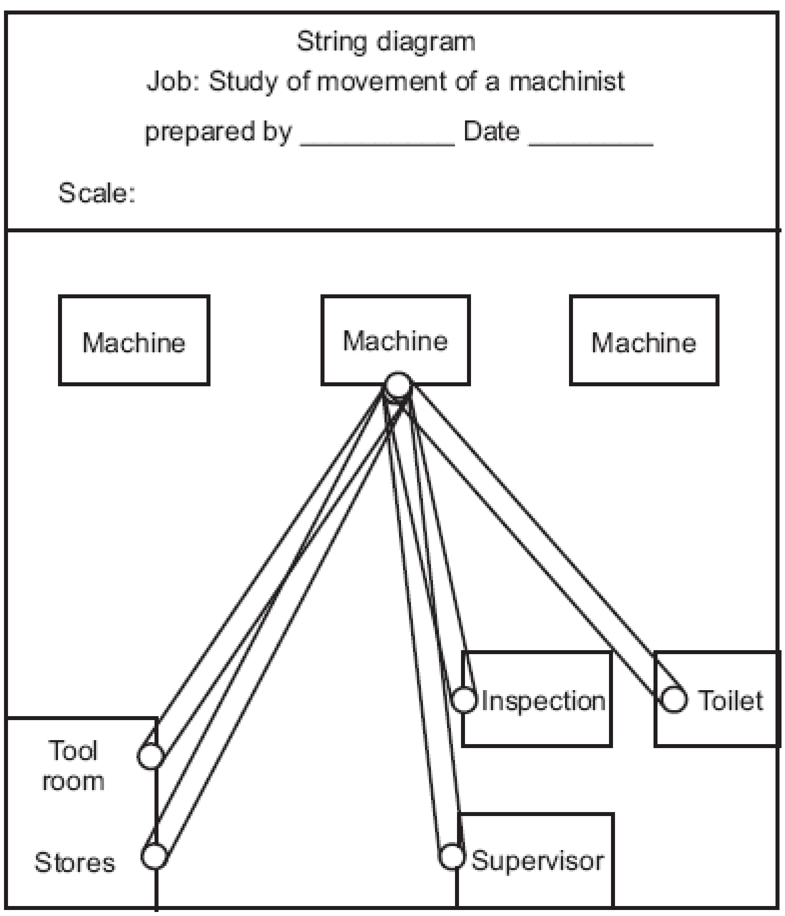
The flow diagram are used for the following purposes:

1. To remove unwanted material movement.
2. To remove back tracking.
3. To avoid traffic congestion.
4. To improve the plant layout.

Conventions adopted are

1. Heading and description of the process should be given at the top of the diagram.
2. Other informations like location, name of the shop, name of the person drawing thediagram are also given.
3. The path followed by the material is shown by a flow line.
4. Direction of movement is shown by small arrows along the flow lines.
5. The different activities are represented by the symbols on the flow lines. (Samesymbols used in flow process chart are used here).
6. If more than one product is to be shown in the diagram different colours are usedfor Each path.

String Diagram



We make use of flow diagram for recording the movement of men or material whenthe movement is simple and the path is almost fixed. But when the paths are many and are repetitive, it may not be possible to record them in a flow diagram. Here a string diagram is used.

String diagram is a scaled plan of the shop. Location of machines and various facilities are drawn to scale in a drawing sheet. Pins are fixed at the various work centres in the drawing sheet. A continuous coloured thread or string is taken round the pins where the material or worker moves during the process.

Constructions

1. Draw the layout of the shop to scale in a drawing sheet.
2. Mark the various work centres like machines, stores, work bench etc. in the diagram.
3. Hold the drawing sheet on a soft board and fix pins at the work centres.
4. Tie one end of a coloured string to the work centre from which the movement starts.
5. Follow the path of the worker to different work centre and accordingly take the thread to different points on the drawing board.
6. At the end of the session note down the number of movements from one workcentre to another.
7. Remove the string and measure the total length of the string. Multiply by the scaleand get the actual distance of movement.

Applications

1. It is used for recording the complex movements of material or men.
2. Back tracking, congestion, bottlenecks, under utilized paths are easily found out.
3. It is used to check whether the work station is correctly located.
4. Used to record irregular movements.
5. Used to find out the most economical route.

& 2.6 CRITICAL ANALYSIS AND DEVELOPMENT

Critical examination of the information recorded about the process in charts / diagrams is the most important phase of the method study. In this, each element of the work, as presently being done and recorded on the chart is subjected to a systematic and progressive series of questions with the purpose of determining true reasons for which it is done. Based on thereasons, improvements are found and adopted into a new method, called better method. This examination, thus requires exhaustive collaboration with everyone whose contribution can prove useful, and also full use of all available sources of technical information. The use of questioning technique reduces the possibility of missing any information which may be useful for the development of better method.

A popular procedure of carrying out critical examination uses two sets of questions: Primary questions (answers to these show up the necessity of carrying out the activity), and Secondary questions (answers to these allow considerations to alternative methods of doing the activity). Selection of the best way of doing each activity is later determined to develop new method which is introduced as a standard practice.

A general-purpose set of primary and secondary questions is given below:

Primary Questions:

1. Purpose. The need of carrying out the activity is challenged by the questions-What isachieved? Is it necessary? Why?

The answers to these questions determine whether the particular activity will be included in the proposals of new method for the process.

2. Means. The means of carrying out the activity are challenged by the questions- 'How is it done?' and 'Why that way'?

3. Place. The location of carrying out the activity is challenged by the questions- 'Where is it done'? and 'Why there'?

4. Sequence. The time of carrying out the activity is challenged by the questions- 'When is it done'? and 'Why then'?

5. Person. The level of skill and experience of the person performing the activity is challenged by the questions- 'Who does it'? and 'Why that person'?

The main object of the primary questions is to make sure that the reasons for every aspect of the presently used method are clearly understood. The answers to these questions should clearly bring out any part of the work which is unnecessary or inefficient in respect of means, sequence, person or place.

Secondary Questions:

The aim of secondary questions is to arrive at suitable alternatives to the presently used method:

1. Purpose. If the answer to the primary question 'Is the activity necessary"? is convincingly 'Yes', alternatives to achieve the object of carrying nut the activity are considered by the question— 'What else could be done'?

2. Means. All the alternative means to achieve the object are considered by the question— 'How else could it be done'?

3. Place. Other places for carry ing out the activity are considered by the question— 'Where else could it be done'?

4. Sequence. The secondary question asked under this heading is— 'When else could it be clone'?

5. Person. The possibilities for carrying out the activity by other persons are considered by asking the question- 'Who else should do it' ?

This phase involves the search of alternative possibilities within the imposed restrictions of cost, volume of production, and the like. For this the method study man uses his own past experience with same or similar problems or refers to text books, handbooks, etc.

The answers to the following questions are then sought through evaluation of the alternatives.'What should be done'?

'How should it be done'? 'Where should it be done'? 'When should it be done'? and'Who should do it'?

These answers form the basis of the proposals for the improved method. The evaluation phase requires the work study man to consider all the possibilities with respect to the four factors—economic, safety, work quality and human factors—the economic factor being the most important in most situations.

Economic considerations to any alternative refer to determination of 'How much will it cost'? and 'How much will it save'? The purpose of evaluating safety factor is to ensure that the alternative selected shall not make the work less safe. The evaluation of quality factor shall determine whether the alternative selected shall make for better product quality or quality control.

And lastly human factors considerations shall ensure that the new method will be interesting,easy to learn, safe, less monotonous and less fatiguing to the operator

Implementation of micro Motion and memo motion study

It is a technique for recording and timing an activity.

• It consists of taking motion pictures of the operation with a clock in the picture (or with a videocamera running at a known speed.

• The film is a permanent record of the method and the time and is always when it is needed.

MICROMOTION STUDY

1. To assist in finding the preferred method of doing the work.
2. To assist in training the workers to understand the meaning of motion study and to enablethem to apply motion economy principles in a professional way.

The procedure of making a micromotion study consists of:

1. Filming the operation to be studied.
2. Analysing the film.
3. Charting the results of the analysis.
4. Developing the improved method.

MEMOMOTION STUDY

In memomotion study, the camera speed is at 60 or 100 frames per minute. In addition to its use in industrial operations, it is used to study many other operations such as check-in operations as airline counters, the manner in which customers select items in the store, traffic flow on highways, and in banks. It costs less than micromotion study (only costs 6% of the cost of a micromotion study).

WORK MEASUREMENT

Work measurement is a technique to establish the time required for a qualified worker tocarry out a specified job at a defined level ofperformance.

Objectives of work measurement

1. To reduce or eliminate non-productive time.
2. To fix the standard time for doing a job.
3. To develop standard data for future reference.
4. To improve methods.

Uses of work measurements

1. To compare the efficiency of alternate methods. When two or more methods are available for doing the same job, the time for each method is found out by workmeasurement. The method which takes minimum time is selected.
2. Standard time is used as a basis for wage incentive schemes.

3. It helps for the estimation of cost. Knowing the time standards, it is possible to workout the cost of the product. This helps to quote rates for tenders.

4. It helps to plan the workload of man and machine.

5. It helps to determine the requirement of men and machine. When we know the time to produce one piece and also the quantity to be produced, it is easy to calculate thetotal requirement of men and machines.

6. It helps in better production control. Time standards help accurate scheduling. Sothe production control can be done efficiently.

7. It helps to control the cost of production. With the help of time standards, thecost of production can be worked out. This cost is used as a basis for control.

8. It helps to fix the delivery date to the customer. By knowing the standard time wewill be able to calculate the time required for manufacturing the required quantity of products.

TECHNIQUES OF WORK MEASUREMENT

The different techniques used in work measurement are

1. Stop watch time study.
2. Production study.
3. Work sampling or Ratio delay study.
4. Synthesis from standard data.
5. Analytical estimating.
6. Predetermined motion time system.

2.13 Time Study and production studyStop Watch Time Study

Stop watch time study is one of the techniques of work measurement commonlyused.

Here we make use of a stop watch for measuring the time.

Procedure for conducting stop watch time study

The following procedure is followed in conducting stop watch time study:

7. Selecting the job.
8. Recording the specifications.
9. Breaking operation into elements.
10. Examining each element.
11. Measuring using stop watch.
12. Assessing the rating factor.
13. Calculating the basic time.
14. Determining the allowances.
15. Compiling the standard time.

1. Selection of job

Time study is always done after method study. Under the following situations, a job isselected for time study:

1. A new job, new component or a new operation.
2. When new time standard is required.

3. To check the correctness of the existing time standard.
4. When the cost of operation is found to be high.
5. Before introducing an incentive scheme.
6. When two methods are to be compared.

2. Record

The following informations are recorded

1. About the product-name, product-number, specification.
2. About the machine, equipment and tools.
3. About the working condition-temperature-humidity- lighting etc. These informations are Used when decidingabout the allowances.
4. About the operator name-experience-age etc. This is needed for rating the operator.

3. Break down operation into elements

Each operation is divided into a number of elements. This is done for easy observationand accurate

measurement. The elements are grouped as constant element, variable element, occasional element, man element, machine element etc.

4. Examine each element

The elements are examined to find out whether they are effective or wasteful. Elementsare also examined whether they are done in the correct method.

5. Measure using a stop watch

The time taken for each element is measured using a stop watch. There are two methods of measuring. *viz.*, Fly back method and Cumulative method. Cumulative methodis preferable. The time measured from the stop watch is known as observed time. Time for various groups of elements should be recorded separately. This measurement has to be done for a number oftimes. The number of observations depend upon the type of operation, the accuracy requiredand time for one cycle.

6. Assess the rating factor

Rating is the measure of efficiency of a worker. The operator‘s rating is found out by comparing his speed of work with standard performance. The rating of an operator is decided by the work study man in consultation with the supervisor. The standard rating is taken as 100. If the operator is found to be slow, his rating is less than 100 say 90. If the operator is above average, his rating is more than 100, say 120.

7. Calculate the basic time

Basic time is calculated as follows by applying ratingfactor

$$\text{Basic time} = \text{Observed time} \times \frac{\text{Operator rating}}{\text{Standard rating}}$$

$$BT = OT \times \frac{OR}{SR}$$

8. ***Determine the allowance***

A worker cannot work all the day continuously. He will require time for rest going for toilet, drinking water etc. Unavoidable delays may occur because of tool breakage etc. So some extra time is added to the basic time. The extra time is known as allowance.

9. ***Compile the standard time***

The standard time is the sum of basic time and allowances. The standard time is alsoknown as allowed time.

Breaking a Job into Elements

It is necessary to break down a task (job) into elements for the followingreasons:

1. To separate productive time and unproductivetime.
2. To assess the rating of the worker moreaccurately.
3. To identify the different types of elements and to measure their timings separately.
4. To determine the fatigue allowanceaccurately.
5. To prepare a detailed workspecification.
6. To fix standard time for repetitive elements (such as switch on or switch off ofmachine).

Classification of elements

1. ***Repetitive elements***

It is an element which occurs in every work cycle of the job.

Example 1.9

Loading the machine, locating a job in a fixture.

2. ***Constant element***

It is an element for which the basic time remains constant whenever it isperformed. Switching on the machine, switching off themachine.

3. ***Variable element***

It is an element for which the basic time varies depending on the characteristicsof the product, equipment or process.

Example 1.11

Saving a log of wood-time changes with diameter or the work.

4. ***Occasional element***

It is an element which does not occur in every work cycle of the job. It mayoccur at regular or irregular intervals.

Example 1.12

Regrinding of tools, re-setting oftools.

5. ***Foreign element***

It is an element which is not a part of the job.

Example 1.13

Cleaning a job that is to be machined.

6. ***Manual element***

It is an element performed by the worker.

Example 1.14

Cleaning the machine, loading the machine.

7. Machine element

It is the element automatically performed by a power driven machine.

Example 1.15

Turning in a lathe using automatic feed.

General rules to be followed in breaking down a task into elements

1. Element should have a definite beginning and ending.
2. An element should be as short as possible so that it can be conveniently timed. The shortest element that can be timed using a stop watch is 0.04mt.
3. Manual elements and machine elements should be separatelytimed.
4. Constant element should be separated from variable elements.
5. Occasional and foreign elements should be timed separately.

Measuring Time with a Stop Watch

There are two methods of timing using a stop watch. They are

1. Fly back or Snap back method.
2. Continuous or Cumulative method.

1. Fly back method

Here the stop watch is started at the beginning of the first element. At the end of the element the reading is noted in the study sheet (in the WR column). At the same time, thestop watch hand is snapped back to zero. This is done by pressing down the knob, immediately the knob is released. The hand starts moving from zero for timing the next element. In this way the timing for each element is found out. This is called observed time (O.T.) .

2. Continuous method

Here the stop watch is started at the beginning of the first element. The watch runs continuously throughout the study. At the end of each element the watch readings are recorded on the study sheet. The time for each element is calculated by successive subtraction. The final reading of the stop watch gives the total time. This is the observed time(O.T.).

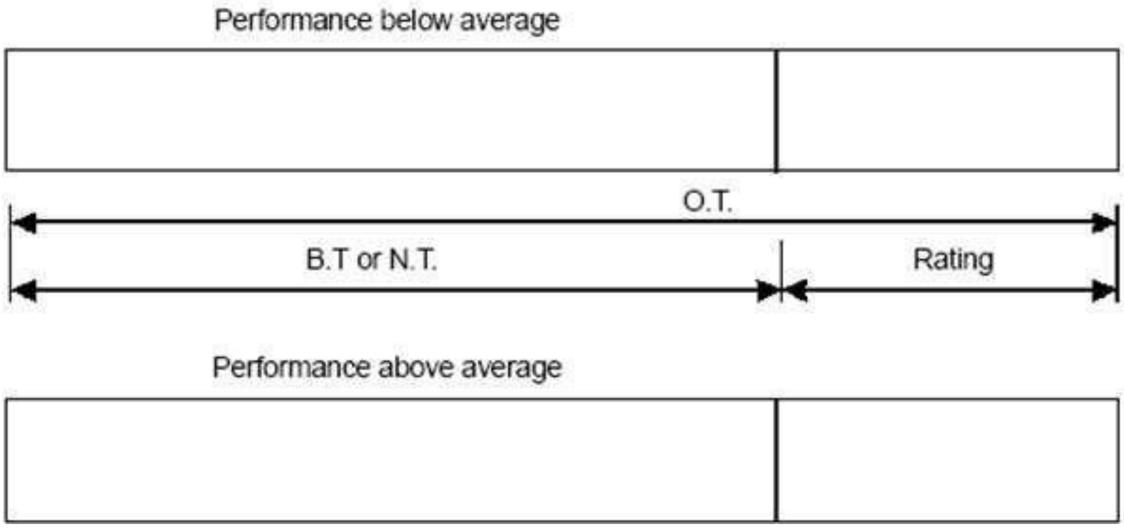
Work sampling

Basic time is the time taken by an operator of standard performance (rating of 100). A man whose work is observed, may be a slow worker or a fast worker. His rating may be less than 100 or above 100. The observed time cannot be taken as the basic time. Here the rating factor is applied and basic time is calculated as follows.

$$\text{Basic time} = \text{Observed time} \times \frac{\text{Operator rating}}{\text{Standard rating}}$$

For example, assume that observed time for an operation is 0.7 mts. The rating ofthe operator is found to be 120.

$$\text{The Basic Time or Normal Time} = 0.7 \times \frac{120}{100} = 0.84 \text{ mts.}$$



ALLOWANCES

Various types of allowance are

1. Rest and personal allowance.
2. Process allowance.
3. Contingency allowance.
4. Special allowance.
5. Policy allowance.

CALCULATION OF STANDARD TIME

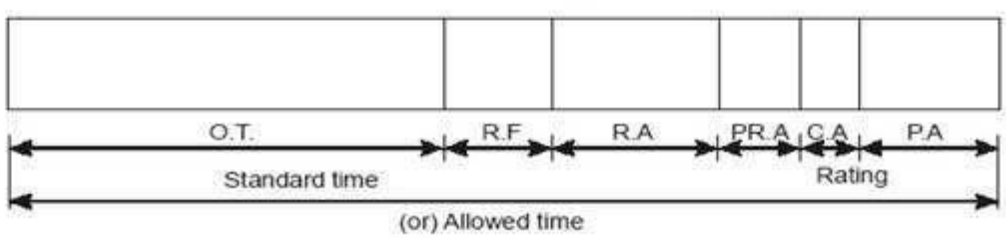
Standard time or allowed time is the total time in which a job should be completed atstandard performance. It is the sum of normal time (basic time) and allowances. Policy allowance is not included.

Standard time is worked out in a stop watch time study in the following manner.

Observed time

This is the actual time observed by using a stop watch. The observed time of an operationis the total of the elemental times.

$$\begin{aligned}&\text{Basic time or}\\&\text{Normal time} = \text{Observed time} \times \frac{\text{Rating of the operator}}{\text{Standard rating (100)}}\end{aligned}$$



OT	–	Observed time	PRA	–	Process allowance
RF	–	Rating factor	CA	–	Contingency allowance
RA	–	Rest allowance	PA	–	Policy allowance

The time study for the same job is conducted for a number of times. The average of the observed times is calculated.

Basic or normal time

Basic time is the time taken by a worker with standard performance. Basic time is calculated from the observed time by applying the rating factor.

Allowed time or standard time

The standard time is obtained by adding the following allowances with the basic or normal time.

1. Rest and personal allowance or relaxation allowance.
2. Process allowance or unavoidable delay allowance.
3. Contingency allowance.
4. Special allowance.

Policy allowance may be added to the standard time if the management wants.

PRODUCTION STUDY

Production study is a technique of work measurement to check accuracy of the original time study. This study is done to find the time delay due to occasional elements. These elements may occur at irregular intervals. Example: Tool grinding, setting tools etc. There are chances of missing these elements in the stop watch time study. Production study is conducted for a longer period—at least for half a day or one shift.

RATIO DELAY STUDY

This study is also known as work sampling or activity sampling. Here the ratio of the delay time and working time to the total time of an activity is found out. This is done by random (irregular) observations. This study is applied to

1. Long cycle operations.
2. Activities where time study is not possible.

SYNTHESIS FROM STANDARD DATA

Synthesis is a work measurement technique to work out standard time for a job by totaling the elemental times already obtained from previous time studies. Many operators in an industry have several common elements. Example: starting the machine, stopping the machine etc. Whenever these activities occur, they take the same duration of time. These elements are called constant elements. Time for some elements vary proportionately with the speed, feed, length of cut etc. in machining operation. These elements are known as variable elements. Time for all these constant elements and variable elements are collected from the time studies previously made. These are stored in a file. This is called time standard data bank. Data bank contains data in the form of

1. Tabulated standard time for constant elements.
2. Charts and graphs.

3. Formulae etc.

ANALYTICAL ESTIMATING

Setting the time standards for long and non-repetitive operations by stop watch method are uneconomical. Analytical estimating technique determines the time values for such jobs either by using the synthetic data or on the basic of the past experience of the estimator when no synthetic or standard data is available. In order to produce accurate results the estimator must have sufficient experience of estimating, motion study, time study and the use of synthesized time standards.

PREDETERMINED MOTION TIME STANDARDS (PMTS)

Definition: PMTS is a work measurement technique where by times, established for basic human motions (classified according to the nature of the motion and the conditions under which it is made) are used to build up the time for a job at a defined level of performance. Few well- known systems using this concept are

1. M.T.M. : Method Time Measurement.
2. W.F.S. : Work Factor System.
3. M.T.A. : Motion Time Analysis.
4. D.M.T. : Dimensional Motion Times.
5. B.M.T. : Basic Motion Times.

UNIT III
PRODUCT PLANNING AND PROCESS PLANNING

Introduction of Product planning

Production planning and control is a tool available to the management to achieve the stated objectives. Thus, a production system is encompassed by the four factors. i.e., quantity, quality, cost and time. Production planning starts with the analysis of the given data, i.e., demand for products, delivery schedule etc., and on the basis of the information available, ascheme of utilization of firms resources like machines, materials and men are worked out toobtain the target in the most economical way.

Once the plan is prepared, then execution of plan is performed in line with the details given in the plan. Production control comes into action if there is any deviation between the actualand planned. The corrective action is taken so as to achieve the targets set as per plan by using control techniques.

Thus production planning and control can be defined as the "direction and coordination of firms' resources towards attaining the prefixed goals." Production planning and control helps to achieve uninterrupted flow of materials through production line by making available the materials at right time and required quantity.

Thus, product planning is required for the following reasons:

(i) To replace obsolete products

(ii) To maintain and increase the growth rate/sales revenue of the

firm(iii)To utilize spare capacity

(iv) To employ surplus funds or borrowing capacity

(v) To diversify risks and face competition

Product planning - Extending the original product information

Product planning

Product planning is the process of creating a product idea and following through on it until the product is introduced to the market. Additionally, a small company must have an exit strategy for its product in case the product does not sell. Product planning entails managing the product throughout its life using various marketing strategies, including product extensions or improvements, increased distribution, price changes and promotions.

Extending the original product information are

Product Design

A product is designed to meet certain functional requirements, and to satisfy the customers' needs. At the same time product must be aesthetically appealing to the customer or user. New technology and new materials currently available will also be explored during the product design stage. A product consists of assemblies, sub- assemblies and component parts. If the product is to be manufactured to customer's specifications, the design is provided by the customer. The manufacturer's product design department will not be involved.

If the product is proprietary, the manufacturing firm is responsible for the design and development of the product. The cycle of events that initiates a new product design often originates from the sales and marketing department. The departments of the firm that are organized to perform the product design function might include, Research and Development, Design engineering, Drafting, and perhaps a Prototype shop.

The product design is documented by means of *component drawings, specifications, and a bill of materials that defines how many of each component go into the product*. A prototype is often built for testing and demonstration purposes. The manufacturing engineering department is sometimes consulted for advice on matters of produceability or manufacturability. Questions like "What changes in design could be made to reduce production costs without sacrificing function" ? are raised and answers sought. Cost estimates are prepared to establish an anticipated price for the product.

Upon completion of the design and fabrication of the prototype, the top company management officials are invited for a presentation and discussion held. The design engineer gives a presentation and demonstration of the product so that management can decide whether to manufacture the item. The decision is often a two-step process. The first is a decision by engineering management that the design is approved. The second step is a decision by top corporate management as to the general suitability of the product. This second decision represents an authorization to produce the item.

Manufacturing Planning

The information and documentation that constitute the design of the product are considered in the *manufacturing planning*. The Departments in the organization that perform manufacturing planning include manufacturing engineering, industrial engineering, and production planning and process planning.

Process Design

Industry employs a set of procedures in the design of manufacturing processes. Generally speaking this activity starts with the receipt of the product specifications and ends with the final plans for the manufacture of the product. In a broad sense this pattern of activity is uniform, regardless of the kind of product or the type of manufacturing involved. The steps involved in process design are as follows.

(i) A careful review of the product design and specifications to make sure that economical manufacture is feasible.

(ii) Determination of the methods of manufacture that will result in the optimum manufacturing cost.

(iii) Selection or development and procurement of all machines, tools, and other equipment required for the manufacture of the product at the required qualityand rate of production.

(iv) Layout of the production area and auxiliary spaces, and installation of the manufacturing facilities.

(v) Planning for and establishing the necessary control of materials, machines, and manpower to ensure the effective utilization of the manufacturing facility for the economical production of the product.

The above steps may be identified as functions of various activities, such as manufacturing engineering, process engineering, process planning methods engineering, or tool engineering. The scope of process-design activity can be identified as all work thatis necessary to arrange for the manufacture of the product by the most economical means.

VALUE ANALYSIS (THE CONCEPT OF VALUE)

The value of a product will be interpreted in different ways by different customers. Its common characteristic is a high level of performance, capability, emotional appeal, style, etc. relative to its cost. This can also be expressed as maximizing the function of a productrelative to its cost:

Value = (Performance + Capability)/Cost = Function/Cost

Value is not a matter of minimizing cost. In some cases the value of a product can be increased by increasing its function (performance or capability) and cost as long as the added function increases more than its added cost. The concept of functional worth can be important. Functional worth is the lowest cost to provide a given function. However, there are less tangible “selling” functions involved in a product to make it of value to a customer.

INTRODUCTION TO VALUE ANALYSIS

Lawrence Miles conceived of Value Analysis (VA) in the 1945 based on the application of function analysis to the component parts of a product. Component cost reduction was an effective and popular way to improve “value” when direct labor and material cost determined the success of a product. The value analysis technique supported cost reductionactivities by relating the cost of components to their function contributions.

Value analysis defines a “basic function” as anything that makes the product work or sell. A function that is defined as “basic” cannot change. Secondary functions, also called “supporting functions”, described the manner in which the basic function(s) were implemented. Secondary functions could be modified or eliminated to reduce product cost.

As VA progressed to larger and more complex products and systems, emphasis shifted to "upstream" product development activities where VA can be more effectively applied to a product before it reaches the production phase. However, as products have become more complex and sophisticated, the technique needed to be adapted to the "systems" approach that is involved in many products today. As a result, value analysis evolved into the "Function Analysis System Technique" (FAST) which is discussed later.

THE VALUE ANALYSIS METHOD

In all problem solving techniques, we are trying to change a condition by means of a solution that is unique and relevant. If we describe in detail what we are trying to accomplish, we tend to describe a solution and miss the opportunity to engage in divergent thinking about other alternatives. When trying to describe problems that affect us, we become locked in to a course of action without realizing it, because of our own bias.
Conversely, the more abstractly we can define the function of what we are trying to accomplish, the more opportunities we will have for divergent thinking.

This high level of abstraction can be achieved by describing what is to be accomplished with a verb and a noun. In this discipline, the verb answers the question, "What is to be done?" or, "What is it to do?" The verb defines the required action. The noun answers the question, "What is it being done to?" The noun tells what is acted upon. Identifying the function by a verb-noun is not as simple a matter as it appears.

Identifying the function in the broadest possible terms provides the greatest potential for divergent thinking because it gives the greatest freedom for creatively developing alternatives. A function should be identified as to what is to be accomplished by a solution and not how it is to be accomplished. How the function is identified determines the scope, or range of solutions that can be considered.

That functions designated as "basic" represent the operative function of the item or product and must be maintained and protected. Determining the basic function of single components can be relatively simple. By definition then, functions designated as "basic" will not change, but the way those functions are implemented is open to innovative speculation.

One objective of value analysis or function analysis, to improve value by reducing the cost-function relationship of a product, is achieved by eliminating or combining as many secondary functions as possible.

VALUE ANALYSIS PROCESS

The first step in the value analysis process is to define the problem and its scope. Once this is done, the functions of the product and its items are derived. These functions are classified into "basic" and "secondary" functions. A Cost Function Matrix or Value Analysis Matrix is prepared to identify the cost of providing each function by associating the function with a mechanism or component part of a product. Product functions with a high cost-function ratio are identified as opportunities for further investigation and improvement.
Improvement opportunities are then brainstormed, analyzed, and selected.

The objective of the Function Cost Matrix approach is to draw the attention of the analysts away from the cost of components and focus their attention on the cost contribution of the functions. The Function Cost Matrix displays the components of the product, and the cost of those components, along the left vertical side of the graph. The top horizontal legend contains the functions performed by those components. Each component is then examined to determine how many functions that component performs, and the cost contributions of those functions.

These totals are normalized to calculate each mechanism's relative weight in satisfying the designated functions. This is where the second difference with the Function-Cost Matrix arises. This mechanism weight can then be used as the basis to allocate the overall item or product cost. The mechanism target costs can be compared with the actual or estimated costs to see where costs are out of line with the value of that mechanism as derived from customer requirements and function analysis.

FUNCTION ANALYSIS SYSTEM TECHNIQUE

Function Analysis System Technique is an evolution of the value analysis process created by Charles Bytheway. FAST permits people with different technical backgrounds to effectively communicate and resolve issues that require multi-disciplined considerations. FAST builds upon

VA by linking the simply expressed, verb-noun functions to describe complex systems.

FAST is not an end product or result, but rather a beginning. It describes the item or systemunder study and causes the team to think through the functions that the item or system performs, forming the basis for a wide variety of subsequent approaches and analysis techniques. FAST contributes significantly to perhaps the most important phase of value engineering: function analysis. FAST is a creative stimulus to explore innovative avenues for performing functions.

The FAST diagram or model is an excellent communications vehicle. Using the verb-noun rules in function analysis creates a common language, crossing all disciplines and technologies. It allows multi-disciplined team members to contribute equally and communicate with one another while addressing the problem objectively without bias or preconceived conclusions. With FAST, there are no right or wrong model or result. The problem should be structured until the product development team members are satisfied thatthe real problem is identified. After agreeing on the problem statement, the single most important output of the multi-disciplined team engaged in developing a FAST model is consensus. Since the team has been charged with the responsibility of resolving the assigned problem, it is their interpretation of the FAST model that reflects the problem statement that's important. The team members must discuss and reconfigure the FAST model until consensus is reached and all participating team members are satisfied that their concerns are expressed in the model. Once consensus has been achieved, the FAST model is complete and the team can move on to the next creative phase.

FAST differs from value analysis in the use of intuitive logic to determine and test function dependencies and the graphical display of the system in a function dependency diagram or model. Another major difference is in analyzing a system as a complete unit, rather than analyzing the components of a system. When studying systems it becomes apparent that functions do not operate in a random or independent fashion. A system existsbecause functions form dependency links with other functions, just as components form a dependency link with other components to make the system work. The importance of the FAST approach is that it graphically displays function dependencies and creates a process to study function links while exploring options to develop improved systems.

3 There are normally two types of FAST diagrams, the technical FAST diagram andthe customer FAST diagram. A technical FAST diagram is used to understand the technicalaspects of a specific portion of a total product. A customer FAST diagram focuses on the aspects of a product that the customer cares about and does not delve into the technicalities, mechanics or physics of the product. A customer FAST diagram is usually applied to a totalproduct.

CREATING A FAST MODEL

The FAST model has a horizontal directional orientation described as the HOW-WHY dimension. This dimension is described in this manner because HOW and WHY questions are asked to structure the logic of the system's functions. Starting with a function, we ask HOW that function is performed to develop a more specific approach. This line of questioning and thinking is read from left to right. To abstract the problem to a higher level,we ask WHY is that function performed. This line of logic is read from right to left.

There is essential logic associated with the FAST HOW-WHY directional orientation. First,when undertaking any task it is best to start with the goals of the task, then explore methodsto achieve the goals. When addressing any function on the FAST model with the question WHY, the function to its left expresses the goal of that function. The question HOW, is answered by the function on the right, and is a method to perform that function being addressed. A systems diagram starts at the beginning of the system and ends with its goal.
A FAST model, reading from left to right, starts with the goal, and ends at the beginning ofthe "system" that will achieve that goal.

Second, changing a function on the HOW-WHY path affects all of the functions to the rightof that function. This is a domino effect that only goes one way, from left to right. Starting with any place on the FAST model, if a function is changed the goals are still valid (functions to the left), but the method to accomplish that function, and all other functions onthe right, are affected.

Finally, building the model in the HOW direction, or function justification, will focus the team's attention on each function element of the model. Whereas, reversing the FAST model and building it in its system orientation will cause the team to leap over individual functions and focus on the system, leaving function "gaps" in the system. A good rule to remember in constructing a FAST Model is to build in the HOW direction and test the logic in the WHY direction.

The vertical orientation of the FAST model is described as the WHEN direction. This is not part of the intuitive logic process, but it supplements intuitive thinking. WHEN is not a time orientation, but indicates cause and effect.

Scope lines represent the boundaries of the study and are shown as two vertical lines on the FAST model. The scope lines bound the "scope of the study", or that aspect of the problem with which the study team is concerned. The left scope line determines the basic function(s) of the study. The basic functions will always be the first function(s) to the immediate right of the left scope line. The right scope line identifies the beginning of the study and separates the input function(s) from the scope of the study.

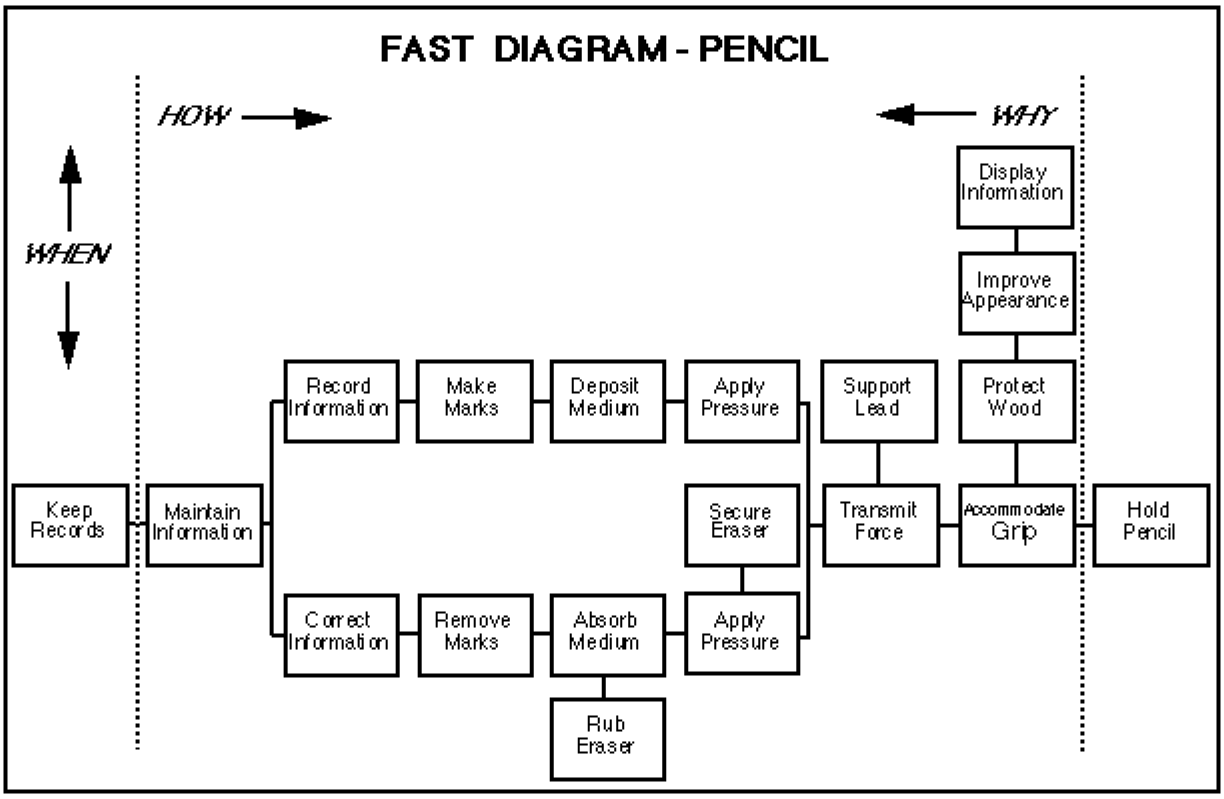
The objective or goal of the study is called the "Highest Order Function", located to the left of the basic function(s) and outside of the left scope line. Any function to the left of another function is a "higher order function". Functions to the right and outside of the right scope line represent the input side that "turn on" or initiate the subject under study and are known as lowest order functions. Any function to the right of another function is a "lower order" function and represents a method selected to carry out the function being addressed.

Those function(s) to the immediate right of the left scope line represent the purpose or mission of the product or process under study and are called Basic Function(s). Once determined, the basic function will not change. If the basic function fails, the product or process will lose its market value.

All functions to the right of the basic function(s) portray the conceptual approach selected to satisfy the basic function. The concept describes the method being considered, or elected, to achieve the basic function(s). The concept can represent either the current conditions (as is) or proposed approach (to be). As a general rule, it is best to create a "to be" rather than an "as is" FAST Model, even if the assignment is to improve an existing product. This approach will give the product development team members an opportunity to compare the "ideal" to the "current" and help resolve how to implement the differences. Working from an "as is" model will restrict the team's attention to incremental improvement opportunities. An "as is" model is useful for tracing the symptoms of a problem to its root cause, and exploring ways to resolve the problem, because of the dependent relationship of functions that form the FAST model.

Any function on the HOW-WHY logic path is a logic path function. If the functions along the WHY direction lead into the basic function(s), than they are located on the major logic path. If the WHY path does not lead directly to the basic function, it is a minor logic path. Changing a function on the major logic path will alter or destroy the way the basic function is performed. Changing a function on a minor logic path will disturb an independent (supporting) function that enhances the basic function. Supporting functions are usually secondary and exist to achieve the performance levels specified in the objectives or specifications of the basic functions or because a particular approach was chosen to implement the basic function(s).

Independent functions describe an enhancement or control of a function located on the logic path. They do not depend on another function or method selected to perform that function. Independent functions are located above the logic path function(s), and are considered secondary, with respect to the scope, nature, level of the problem, and its logic path. An example of a FAST Diagram for a pencil is shown below.



Adapted from an example developed by J. Jerry Kaufman

The next step in the process is to dimension the FAST model or to associate information to its functions. FAST dimensions include, but are not limited to: responsibility, budgets, allocated target costs, estimated costs, actual costs, subsystem groupings, placing inspection and test points, manufacturing processes, positioning design reviews, and others. There are many ways to dimension a FAST model. The two popular ways are called Clustering Functions and the Sensitivity Matrix.

Clustering functions involves drawing boundaries with dotted lines around groups of functions to configure sub-systems. Clustering functions is a good way to illustrate cost reduction targets and assign design-to-cost targets to new design concepts. For cost reduction, a team would develop an “as is” product FAST model, cluster the functions into subsystems, allocate product cost by clustered functions, and assign target costs. During theprocess of creating the model, customer sensitivity functions can be identified as well as opportunities for significant cost improvements in design and production.

Following the completion of the model, the subsystems can be divided among product development teams assigned to achieve the target cost reductions. The teams can then select cost sensitive sub-systems and expand them by moving that segment of the model to a lower level of abstraction. This exposes the detail components of that assemblyand their function/cost contributions.

INTEGRATING QFD WITH FAST

A powerful analysis method is created when FAST is used in conjunction with QFD. QFD enables the uses of the Value Analysis Matrix. An example of a value analysismatrix for the pencil example is shown below.

Customer Requirements/ Functions	Importance	Mechanisms				
		Lead	Eraser	Body	Paint	Band
Make Marks	30	⊙ 150				
Remove Marks	20		⊙ 100			
Prevent Smudges	15	o 45		o 45		
Support Lead	5			⊙ 25		
Improve Appearance	10			o 30	o 30	Δ 10
Accomodate Grip	20			⊙ 100	Δ 20	
Column weight	555	195	100	200	50	10
Mech. weight	1.0	.351	.180	.360	.090	.018
Mech. target cost	2.80	.98	.51	1.01	.25	.05
Mech. actual cost	2.92	1.20	.43	.94	.10	.25

⊙ Strong correlation weight factor = 5

o Moderate correlation weight factor = 3

Δ Weak correlation weight factor = 1

The steps for using these two methodologies are as follows:

1. Capture customer requirements and perform QFD product planning with the product planning matrix. Translate customer needs into directly into verb-noun functions or use a second matrix to translate technical characteristics into verb-noun functions.
2. Prepare a FAST diagram and develop the product concept in conjunction with the QFD concept selection matrix. Review the verb-noun functions in the QFD matrixand assure that they are included in the FAST diagram. Revise verb-noun functiondescriptions if necessary to assure consistency between the QFD matrix and the FAST diagram.
3. Dimension the system in the FAST diagram into subsystems/assemblies/parts. These are generically referred to as mechanisms.
4. Develop value analysis matrix at system level. The "what's" or system requirements/function in the value analysis matrix are derived from either a customer (vs. technical) FAST diagram or by selecting those function statements that correspond to the customer needs or technical characteristics in the product planning matrix. The importance rating is derived from the product planning matrixas well.
5. Complete the value analysis matrix by relating the mechanisms to the customer requirements/functions and calculate the associated weight. Summarize the column weights and normalize to create mechanism weights. Allocate the target cost based on the mechanism weights. This represents the value to the customer based on the customer importance. Compare with either estimated costs based on the product concept or actual costs if available.
6. Identify high cost to value mechanisms / subsystems by comparing the mechanismtarget costs to the mechanism estimated/actual costs

A product or system such as an automobile contains a great many components and would result in an extremely complex FAST model. The complexity of the process is not governed by the number of components in a product, but the level of abstraction selected toperform the analysis. With an automobile, a high level of abstraction could contain the major subsystems as the components under study, such as: the power train, chassis, electrical system, passenger compartment, etc. The result of the FAST model and supporting cost analysis might then focus the team's attention on the power train for further analysis. Moving to a lower level of abstraction, the power train could then be divided into its components (engine, transmission, drive shaft, etc.) for a more detailed analysis.

In other words, the concept of decomposition is applied to a FAST model. The initial FAST model will stay at a high level of abstraction. Starting at a higher level of abstraction allows for uncluttered macro analysis of the overall problem until those key functions can be found, isolated, and the key issues identified. If a function is identified for further study, we note that with a "^" below the function box. A supporting FAST diagram is then created for that subsystem function. This process of decomposition or moving to lower levels of abstraction could be carried down several levels if appropriate.

Once high cost to value mechanisms are identified in the initial system value analysis matrix, the next step is to focus more attention on those mechanisms and associated functions. Dimensioning groups the functions together into those associated with a particular subsystem, assembly or part. The FAST diagram can be expanded into a lower level of abstraction in the area under investigation. The steps involved are as follows:

1. Use QFD to translate higher-level customer needs to subsystem technicalcharacteristics.
2. Create FAST diagram at lower level of abstraction for targetedmechanism/subsystem.
3. Prepare a FAST diagram & develop the product concept in conjunction with theQFD concept selection matrix
4. Dimension the system in the FAST diagram into assemblies/parts or identify theassemblies/parts needed to perform the given function.
5. Develop value analysis matrix at a lower level of abstraction for the targeted subsystem. The "what's" or system requirements/function in the value analysis matrix are derived from either a customer (vs. technical) FAST diagram or by selecting those function statements that correspond to the customer needs or technical characteristics in the subsystem planning matrix.
6. Complete the value analysis matrix and identify high cost to value mechanisms bycomparing the mechanism target costs to the mechanism estimated/actual costs

VALUE IMPROVEMENT PROCESS

Performing value analysis or producing the FAST model and analyzing functions with the value analysis matrix are only the first steps in the process. The real work begins with brainstorming, developing and analyzing potential improvements in the product. Thesesubsequent steps are supported by:

- The QFD Concept Selection Matrix is a powerful tool to evaluate various concept and design alternatives based on a set of weighted criteria that ultimately tie back tocustomer needs.
- Benchmarking competitors and other similar products helps to see new ways functions can be performed and breaks down some of the not-invented-here paradigms.
- Product cost and life cycle cost models support the estimating of cost for the Function-Cost and Value Analysis Matrices and aid in the evaluation of variousproduct concepts.
- Technology evaluation is leads us to new ways that basic functions can be performed in a better or less costly way. Concept development should involve people with a knowledge of new technology development and an open mind to identify how this technology might relate to product functions that need to be performed. Methods such as the theory of inventive problem solving or TRIZ areuseful in this regard.
- Design for Manufacturability/Assembly principles provide guidance on how to better design components and assemblies that are more manufacturable and, as aresult, are lower in cost.

Value Analysis or Function Analysis provide the methods to identify the problem and to begin to define the functions that need to be performed. As we proceed in developing a FAST model, implicit in this process is developing a concept of operation for the product which is represented by all of the lower order functions in a FAST diagram.

Concept alternatives will be developed through brainstorming, benchmarking other products performing similar functions, and surveying and applying new technology. Since multiple concepts need to be evaluated, we want to use a higher level of abstraction for the FAST model to provide us with the greatest flexibility and a minimum level of effort. Trade studies and technical analysis will be performed to evaluate various product concepts. A concept selection matrix is a good tool to summarize a variety of different data and support making a decision about the preferred concept.

All of these steps may be iterative as a preferred concept evolves and gets more fully developed. In addition, there should be a thorough evaluation of whether all functions are needed or if there is a different way of accomplishing a function as the concept is developed to a lower level of abstraction. When a Function Cost or Value Analysis Matrix is prepared, functions that are out of balance with their worth are identified, further challenging the team to explore different approaches.

SUMMARY

Value analysis and its more robust cousin, Function Analysis System Technique, are important analysis tools. These methodologies lead to improved product designs and lowercosts by:

Providing a method of communication within a product development team andachieving team consensus

- Facilitating flexibility in thinking and exploring multiple concepts
- Focusing on essential functions to fulfill product requirements
- Identifying high cost functions to explore improvements

PROBLEMS IN LACK OF PRODUCT PLANNING

There are three basic factors that affect the design of a manufacturing process, namely:

(i) The volume or quantity of the product to be manufactured.

(ii) The required quality of the product.

(iii) The equipment that is available, or that can be procured, for the manufacture of the product.

The volume to be manufactured must always be considered as the volume to be produced within a given period — or as the rate of production. In this manner it can be related to the capacity of the manufacturing equipment under consideration and the best methods selected accordingly.

The anticipated volume should be based also upon a sales forecast. This is of particular importance in the introduction of a new product. Funds should be allocated for the improvement of processes only when the forecast indicates such a volume of sales thatan appropriate return on the investment can be realized.

Generally speaking, the greater the volume of the product to be produced, the greater is the opportunity to incorporate advanced methods of manufacture into the design of the manufacturing process.

The number of identical units to be produced vitally affects the selection of manufacturing methods. The savings per unit of product or per component part, when multiplied by the total volume to be produced will give an idea of the money that can be allocated for the purchase of modern equipment. It may justify new and better machine tools, the use of numerically controlled machines, etc. It will also justify better auxiliary equipment such as jigs, fixtures, or dies, which will in turn increase the productive capacity of the existing equipment in the plant.

Methods of manufacture vary widely with the volume to be produced. The production of heavy industrial equipment and machinery involves very few units of product, requires skilled machinists or other craftsmen using general-purpose machines and tools, and assembly is by skilled labour. On the other hand, the mass production of washing machines, refrigerators, TVs, automobiles, and similar goods is accomplished with a large proportion of automatic machinery and on a planned assembly line that requires a minimum of skill.

PROCESS PLANNING AND ROUTING

Process plan : The detailed instructions for making a part or a component. It includessuch information as the operations, their sequence, machines, tools, speeds and feeds, dimensions, tolerances, stock removed, inspection procedures and time standards (*i.e.*, cycle time).

Process planning

It may be defined as the determination of the processes and the sequence of operations required to make the product. It consists of devising, selecting and specifying processes, machine tools and other equipment to transform the raw material into finished product as per the specifications called for by the drawings.

The purpose of process planning is to determine and describe the best process for each job so that:

(i) Specific requirements are established for which machines, tools and other equipment can be designed or purchased.

(ii) The efforts of all engaged in manufacturing are co-ordinated.

(iii) A plan is made to show the best way to use the existing or proposed facilities.

After findizing all the details of Product Design, manufacturing planning is to becarried out. Process planning is an integral part of manufacturing planning.

Process planning consists of determining the sequence of the individual processing and assembly operations needed to produce the part.

Routing

Routing may be defined as the planning of where and by whom work shall be done, the path or route to be followed by the work and necessary sequence of operations. Taking from raw material to the finished product, routing decides the path and sequence of operations to be performed on a job. Routing starts from the component drawings and aims at optimum utilization of resources. Routing forms the basis for the scheduling and dispatching functions of the production control department.

Routing Procedure : The following procedure is generally adopted for routing :

(i) From the drawings the final product is analysed from manufacturing pointof view and broken into sub-assemblies and components.

(ii) A detailed bill of materials is prepared.

(iii) Based on the facilities and capacities available, a decision is taken regarding the components which can be manufactured in the plant and which can be bought from outside.

(iv) For each component to be manufactured in the plant, the operations which must be performed to transform the raw material into final shape are established and listed in proper sequence.

(v) A list of tooling required of each stage is also prepared. The information obtained in step (*iv*) and (*v*) is recorded in a sheet called **Route Sheet,** along with other information like component name, Part No., material, quantity to be produced, etc.,

Table 2.4 : Route Sheet

Component No... Name of component.....................................

Material..

....

Operation No	*Deptt./ Secti*	*Operation Description*	*Machine*	*Tool required*	*Cutting data*	*Jigs/ Fixtures and other*

Pre requisite information needed for process planning-

Plan Prerequisites

Information disaster planning is only effective when it is part of a comprehensive information and records management program. A plan to protect business records is ineffective and needlessly expensive if the majority of the protected records no longer have administrative, legal, fiscal, research or historical value. To reconstruct or salvage outdatedor non-essential records is a waste of time and money. More frequently, the lack of approved retention authorizations or not following the retention authorization creates a large body of records that might not be essential or useful to a department. A major disasteris not the appropriate time to conduct a comprehensive review of your records retention authorizations and compliance.

Prerequisite 1: Information is Viewed as a Resource

Departments that are committed to managing information throughout the total life cycle, from creation or inception, through its use, storage, retrieval, to its final disposition, are more likely to properly place disaster planning in their total management program.

Prerequisite 2: Adequate General Insurance

An information disaster plan is a form of insurance. Disaster prevention planning is a form of risk assessment. The planning process presupposes that business insurance programs are in place to protect the University's assets and to provide adequate liability protection. Such programs should already be identified and provide protection against certain risks and dangers.

Risk assessment is a management tool for determining the likelihood of a disaster and its financial impact on the University. A specific dollar amount is placed on each potential disaster by calculating an Annual Loss Expectancy (A.L.E.). The A.L.E. is determined by multiplying the frequency of occurrence by the expected dollar loss per occurrence.

An information disaster plan complements existing insurance by scrutinizing the University from an information vantage point. The plan identifies specific risks such as building and equipment hazards that can result in flooding to records storage areas, dangerous storage practices that increase the risk of fire near irreplaceable research and development records, and periodic electric storms or tornados that endanger electronically generated vital records. High, medium or low disaster plans have a price tag, but an ounceof prevention is better than a pound of cure.

Prerequisite 3: A Vital Records Program

In the event of a disaster, recovery can be very costly. It is important that protected, reconstructed, salvaged, and restored records contain information that is essential to the department's continued operation (vital records).
The identification and protection of essential records represents the gray area where a vitalrecords program and a disaster plan overlap.

Prerequisite 4: A Current Records Retention Schedule

A vital records program is built upon a detailed records retention schedule -- a comprehensive list of records indicating the length of time each record is maintained in theoffice area, in the records center, or on electronic media devices and when and if it can be destroyed.

The retention schedule must precede the vital records protection and disaster recovery plan. This schedule provides necessary information about the location of records, media upon which records are stored, methods of protection, and the value of individual records.

Prerequisite 5: A Sound Records Classification and Retrieval System

Jumbled, poorly labeled records, whether stored in a bulging file folder, in a disorganized microfilm system, or on a poorly indexed electronic system, significantly increase the cost of disaster planning. The main difficulty is that records are not grouped into workable records series -- a group of identical or related records that are normally usedand filed as a unit -- that can be evaluated as a unit for retention scheduling purposes.

Prerequisite 6: An Adequate Security Program

A general security program for both facilities and information provides the necessaryframework to develop an information disaster plan. The following is just a few security elements found in an adequate program:

- Computer passwords/password protection
- Employee identification cards
- Security personnel
- Restricted access areas
- Fire vaults and safes
- Smoke detectors

Summary

Management's commitment to establishing and maintaining a sound records classification and retrieval system, vital records program, current records retention schedules and security is the foundation for building an information disaster prevention andrecovery plan.

An information disaster recovery plan is interactive with these prerequisites. Some elements may be fully in place before the disaster planning process begins; others may onlybe in the elementary stage.

Clearly, any department wanting to protect its recorded information must protect the facility where the records are housed. Unlike "acts of God," disasters caused by building or equipment failure or malfunction can be avoided. Human error or carelessness is frequentlythe cause of fire, water damage, theft, misinformation, and information loss.

The following represents only a few causes of potential department disasters:

- Smoldering cigarette
- Unlocked window or door
- Negligent storage of flammable materials
- Careless computer keystrokes
- Broken water lines/floods
- Power outages
- Weather (ice, heat & storms)
- Terrorist activities
- Cyber threats

An information disaster prevention and recovery plan begins with a clear, workable definition of disaster. The plan addresses the major types of disasters -- fire, flood, bombing, theft, tornado, etc. It clearly delineates the precise circumstances for activating the disaster recovery procedures. These circumstances are easily defined by identifying the number of hours or days your business operation is shut down by the event, whether recovery is handled in-house or contracted with outside sources.

Process plan : The detailed instructions for making a part or a component. It includes such information as the operations, their sequence, machines, tools, speeds and feeds, dimensions, tolerances, stock removed, inspection procedures and time standards (*i.e.*, cycle time).

Process planning

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(iv) For each component to be manufactured in the plant, the operations which must be performed to transform the raw material into final shape are established and listed in proper sequence.

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Table 2.4 : Route Sheet

Component No.. Name of component....................................

Material...

....

Drawing No...................................... Quantity...

Operation No	*Deptt./ Secti*	*Operation Description*	*Machine*	*Tool required*	*Cutting data*	*Jigs/ Fixtures and other*

STEPS INVOLVED (PROCEDURE) IN PROCESS PLANNING

The following are the steps involved in carrying out the process planning manually. Past experience of process planners are used in arriving at the economical manufacturing of the product.

The steps involved in process planning are :

(i) The finished product is analyzed so that its sub-assemblies and individual components are identified from manufacturing point of view.

(ii) Prepare a Bill Of Materials [BOM] for all components of the product which forms a basis for purchase of raw materials.

(iii) Decide which parts are to be manufactured in the plant and which parts are to be purchased from the market depending upon the facilities available in the plant, *i.e.,* decision with regard to "make" or "buy" to be taken.

(iv) Choose the appropriate blank size *i.e.*, raw material size and select the most economical process to be followed to manufacture components of the product. This is done by comparing the various possible methods of obtaining the final product. The basic factors of volume to be produced, *i.e.*, production quantity, required quality of the product and the capabilities of the equipment available are carefully considered in this step.

(v) Decide the sequence of operations to be performed on each component in the process selected.

(vi) Each operation is assigned to the type and size of machine or work station that will perform the job most economically.

(vii) Depending upon the accuracies called for by the drawings, determine themachine tools to do the operations

(viii) Determine the need for any special equipment like jigs, fixtures, cutting toolsetc.,

(ix) Determine the inspection stages and instruments required and the need fordesigning any inspection devices (say gauges, etc.).

(x) Estimate the standard time for performing the job.

(xi) Determine the type of labour (skilled, semi-skilled or unskilled) required to do the job. Process planning has been traditionally carried out by methods engineers, manufacturing engineers, industrial engineers or by process planners.

PROCESS PLANNING SHEET

The whole information determined by the process planning is recorded in a tabular form in a sheet called process planning sheet. This document is provided to the shop personnel for their use. The character of this sheet will very for different organizations depending upon the production conditions and degree of details required.

In general the following data is listed for each component of the product in the process sheet.

(i) Information regarding the main product, of which the component being manufactured is a part *i.e.,* name and part number of the main product.

(ii) Name, part number, drawing number of the component and number off *i.e.*, no. of components required per product.

(iii) Information concerning the blank *i.e.*, raw material used, size and weight ofstock.

(iv) Operations are listed in proper sequence along with the shops in which theseoperations will be performed.

(v) Information regarding machines used for each operation.

(vi) Data on jigs, fixtures and other special tools required.

(vii) Inspection devices needed for inspection.

(viii) Cutting data *i.e.*, speeds, feeds & depth of cut for each machining operation.

(ix) Elements of standard time such as set-up time, handling time and machiningtime for the job.

A typical process sheet is shown in Table 2.3.

The process planning sheet is prepared by the process engineer in consultation withthe tool engineer, industrial engineer, or methods engineer.

Quantity determination in batch production

Batch Production

In this type, the products are made in small batches and in large variety. The orders may berepeated with intervals of time.

The characteristics of this type of production are:
(i) Products are manufactured in batches.
(ii) General purpose machines are used.
(iii) Flow of material is intermittent.
(iv) Plant layout is process type.
(v) In process inventory is high.
(vi) Process and product planning is done for each batch.
(vii) Work loads on various machines or sections are unbalanced.
(viii) Machine operators are highly skilled.
Batch production is also a form of intermittent production. This is a very common type of production. Drugs, chemicals, paints, sheet metal components, forgings and parts manufactured on
turret/capstan lathes come under this type.

Quantity determination in batch production

The **economic production quantity** model (also known as the **EPQ model**) determines the quantity a company or retailer should order to minimize the total inventory costs by balancing the inventory holding cost and average fixed ordering cost. The EPQ model was developed by E.W. Taft in 1918. This method is an extension of the economicorder quantity model (also known as the EOQ model). The difference between these two methods is that the EPQ model assumes the company will produce its own quantity or the parts are going to be shipped to the company while they are being produced, therefore the orders are available or received in an incremental manner while the products are being produced. While the EOQ model assumes the order quantity arrives complete and immediately after ordering, meaning that the parts are produced by another company and are ready to be shipped when the order is placed.

In some literature, "economic manufacturing quantity" model (EMQ) is used for "economic production quantity" model (EPQ). Similar to the EOQ model, EPQ is a single product lot scheduling method. A multiproduct extension to these models is called *product cycling problem*.

Overview EPQ only applies
each new order is delivered/produced incrementally when the inventory reaches zero. There is a fixed cost charged for each order placed, regardless of the number of units ordered.
There is also a holding or storage cost for each unit held in storage (sometimes expressed asa percentage of the purchase cost of the item).

We want to determine the optimal number of units of the product to order so that weminimize the total cost associated with the purchase, delivery and storage of the product

The required parameters to the solution are the total demand for the year, the purchase cost for each item, the fixed cost to place the order and the storage cost for each item per year. Note that the number of times an order is placed will also affect the total cost,however, this number can be determined from the other parameters

Assumptions

1. Demand for items from inventory is continuous and at a constant rate
2. Production runs to replenish inventory are made at regular intervals
3. During a production run, the production of items is continuous and at a constant rate
4. Production set-up/ordering cost is fixed (independent of quantity produced)
5. The lead time is fixed
6. The purchase price of the item is constant, i.e. no discount is available

7. The replenishment is made incrementally

Variables

- K = ordering/setup cost
- D = demand rate
- h = holding cost
- T = cycle length
- P = production rate
- Q = order quantity

Total Cost function and derivation of EPQ formula

Machine capacity, balancing in production

Calculation of Man-Hours and Machine-Hours

A man-hour is defined as the availability of one man (operator) for one hour for doing a job. Availability of man-hours is calculated when the work is done by manual labour as in a scooter assembly shop, welding, making sand moulds and cores in a foundry shop, packing of soaps and detergents, etc. The requirement of man-hours is calculated to estimate the number of men (operators) required to complete the job.

A machine-hour is defined as the availability of one machine for one hour. Availability of machine-hours is calculated in production when work is done mainly with the help of machines as in the case of production with automatic machines, in gear shops manufacturing gears, or using lathe for machining turned components etc.

The requirement of machine hours is calculated to estimate the number of machines required to complete the job.

The number of man-hours or machine-hours available during a particular period is calculated as follows :

(*a*) Total number of days in the period under consideration = X

(*b*) Number of holidays in the period = A

(*c*) Number of shifts per day = B

(*d*) Number of hours per shift = C

Numbers of working hours available = (X – A) × B × C

This gives the total or gross man-hours or machine-hours available for working. But

in
actual practice allowances for absenteeism, power failures, repair and maintenance, rest and other factors have to be considered. The actual or net machine-hours or man-hours available is less than the gross man-hours or machine-hours available and it dependson the type of industry and type of labour available.

Example : Calculate the net machine-hours available in a factory from the following data for month of June :

(1) Number of milling machines
= 8 (2) Number of working days
= 25 (3) Number of shifts per day
= 2

(4) Time lost due to maintenance and repairs, etc. = 3 hrs. per day

(5) Number of hours/shift = 8

Solution : For One Milling Machine :

Number of working days in June = 25

Net working hours available per day/machine = (8 × 2) – 3
= 13 hrs. Net machine-hours available per machine per month = 13
× 25 = 325 hrs.

Net machine-hours available for 8 machines/month = 325 × 8 = 2600 m/c hrs.

Analysis of process capabilities in a multi product system.

There are different levels of involvement of the computer in the operations of any plant or industry.

The computer is used indirectly to support the production function but there is no direct connection between the computer and the process. The computer is used "off-line" to provide information for the effective planning and management of production activities.

Cost Estimating using Computers : The task of estimating the cost of a new product has been simplified in most industries by computerizing several of the key steps required to prepare the estimate. The computer is programmed to apply the appropriate labour and overhead rates to the sequence of planned operations for the components of new products. The programme then sums up the individual component costs from the engineering bill ofmaterials to determine the overall product cost.

Computer Aided Process Planning (CAPP) : Process planning is concerned with the preparation of route sheets which list the sequence of operations and work centres required to produce the product and its components. CAPP systems are available today to prepare these route sheets.

Process planning involves the preparation and documentation of the plans for manufacturing the products. Computer-Aided Process Planning (CAPP) is a means of implementing this planning function by the use of computers

Computer Aided Process Planning represents the link between design and manufacturing in a CAD/CAM system. Process planning is concerned with determining the sequence of processing and assembly steps that must be accomplished to make the product. The processing sequence is documented on a sheet called a route sheet. The route sheet typically lists the production operations, machine tools, work centres or work stations where each operation is performed, jigs, fixtures and tooling required and standardtime for each task.

In manufacturing enterprises, there has been an interest in automating the task of process planning by means of CAPP systems. The shop-trained engineers who are familiar with the details of machining and other processes will be retiring, and these experienced engineers will not be available in the future to do the process planning. An alternative way of accomplishing this function is needed and CAPP systems are providing this alternative.

Computer Aided Process Planning (CAPP) Systems are designed with two approachesin mind. These approaches are called :

(*a*) Retrieval CAPP Systems, and (*b*) Generative CAPP Systems,

Approaches to process planning : Details given earlier are the basic steps involved in process planning when it is carried out manually by an experienced process planner. CAPP (Computer Aided Process Planning) involves the use of an interactive computer system to automate the works involved in preparing a process plan. There are fundamentally **two different approaches** when computers are used in the process planning task.

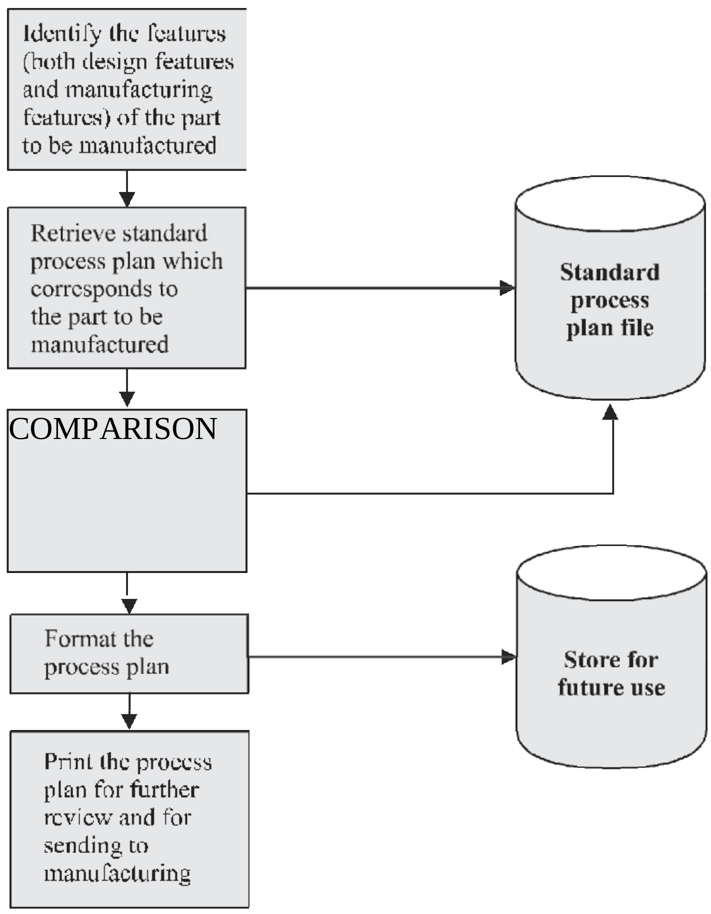
(1) Variant or Retrieval method of process planning.

(2) Generative method of process planning.

1. Variant or Retrieval Method of Process Planning (Retrieval CAPP System)

In this method, the computer makes a search of its storage or a data base or a no. of standard or completed process plans that have been previously developed by the company's process planners. The development of the data base of these process plans requires substantial knowledge of machining, time and efforts. Using the current design data supplied by the CAD system, (after a component has been designed and dimensioned), it searches for a process plan that was based on a part of similar design. (This search can make effective use of GT, Group Technology, design coding to simplify the search for similar part design).

The process plan **retrieved** is then modified or suitably **varied** (*i.e.*, altered) by the process planner, to suit the exact requirements of the current part design. The useof Computer and Group



Procedure for developing the Retrieval type Computer—Aided Process Planning (CAPP) system

Technology (GT) to search for the most appropriate or similar part design, and to retrieve the process plan for that design, significantly reduces the work required of the process planners. This also saves considerable amount of time required to develop a process plan for a new part. The task of process planner becomes one of modifying the existing plan to suit the particular dimensions of the current part. (*i.e.,* the selected process plan is provided to the user for modification and variation).

Process planners are required to perform the entire process planning method only in the case of a completely new part design.

This approach of process planning is also known as Retrieval CAPP system. This is based on the principles of Group Technology and parts classification and coding. One of the pre-requisites for implementation of this method is that the industries must develop and maintain a large computer data base of standard completed process plans. In addition, the part designs are to be developed using CAD systems.

2. Generative Method of Process Planning (Generative CAPP System)

The second method of computerized process planning is the generative method. Inthis method the computer uses the stored manufacturing and design data to generate a complete list of all possible process plans that could be used to manufacture the current part. It then exhaustively searches this list for the one which optimizes the cost function. This method always yields the optimum process plan for manufacturing a particular part.

However, it has a very high cost in terms of time and computer processing expenses. The computations required to provide even a single process plan for an arbitrary part design can be enormously complex. To repeat this for every feasible process plan or apart can become very costly.

This approach of process planning is also known as **Generative CAPP System.** Both the approaches viz. Variant (or retrieval) method of process planning and Generative method of process planning involves a systematic development of Code Numbers using Group Technology concepts and principles for the design and manufacture of the part. Both of these methods of computerized process planning can be enhanced through the application of AI (Artificial Intelligence) in the form of expert systems.

Benefits of CAPP

The benefits derived from computer aided process planning are the following

1. **Process rationalization and standardization :** Automated process planning leads to more logical and consistent process plans than when process planning is done completely manually.
2. **CAPP helps in arriving at standard and consistent process plans :** Standard plans tend to result in lower manufacturing costs and higher product quality.
3. **Increased productivity of process planners :** The systematic approach and the availability of standard process plans in the data files permit more work to be accomplished by the process planners.
4. **Reduced lead time for process planning :** Process planners working with the CAPP system can provide route sheets in a shorter lead time compared to
manual preparation.
5. **Improved legibility and readability :** Computer prepared route sheets are legible and easier to read than manually prepared route sheets.
6. **Incorporation of other application programmes :** The CAPP programme can be integrated with other application programmes, such as estimation of standard time, cost estimating and formulation of work standards.

Practices of Process Planning

The practices of process planning vary widely in modern industry, depending on such factors as :

- Type of product

- The equipment available, and
- The volume of production (*i.e.*, production quantity)

The individual responsible for carrying out process planning / process analysis is the Process Engineer also known as process planner, process analyst or methods engineer. To be effective on his or her job, the process analyst must be familiar with material characteristics and manufacturing processes. Knowledge of the nature, types, and properties of standard materials and new materials will assist the process analyst in selecting the most appropriate process, equipment and methods for manufacturing a particular product. The process analyst must also be familiar with engineering drawings and product design. Drawings provide the part configuration and the dimensional tolerances and specifications that need to be met by the manufacturing process selected

In addition, the process planner must be familiar with the operating characteristicsand costs of the production and tooling equipment, either available in the plant or to be purchased.

Process Planning starts with a careful examination of the drawing or design of the part. The process planner must be able to analyze the engineering drawing and visualize the three dimensional part configuration. The part configuration must then be analyzed to determine its basic geometric components. Identifying these basic geometric elements assists the process planner in selecting the most appropriate process to manufacture the product.

Process Selection

Consideration should be given to the following factors in selecting a particular process

1. Nature of part, including materials, tolerances, desired surface finish and operation required.
2. Method of fabrication including machining or assembling of similar parts orcomponents.
3. Limitation of facilities including the plant and equipment available.
4. Possibility of likely product design changes to facilitate manufacturability or cost reduction.
5. In-plant and outside materials handling systems.
6. Inherent process to produce specified shape, surface, finish to give desiredmechanical properties.
7. Available skill level of operators for the production.

Sometimes the following additional factors affect the selection of a particular process.

(a) Proposed or anticipated production requirements, including volume requirements, production rates and short- term or long- term production runs.

(b) Total end-product costs.

(c) Time available for tooling-up.

(d) Materials receipt, storage, handling and transportation.

Careful consideration of these factors will result in the selection of the most appropriate process for the manufacture of a particular product.

Selection of an appropriate manufacturing process depends on many factors and requires considerable knowledge, skill and competence of the process planner or process analyst.

Process Sheet : Once the process (example : machining) has been selected, the next step is to list operations in a logical sequence. The processes are written in a sequential order in the process sheet or operation analysis sheet. The process sheets are used as instruction sheets, for the operator to process the part.

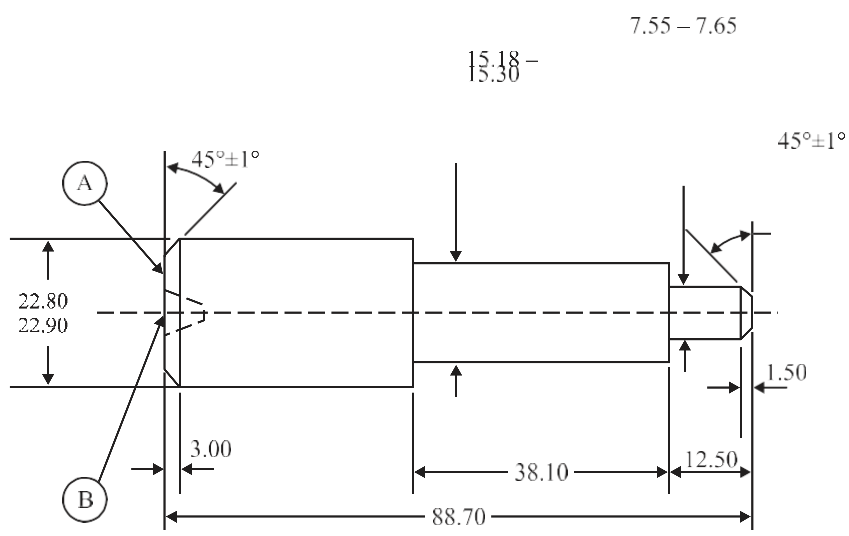
Process sheets format vary widely in industry depending on such factors as type of product, type of industry, type of equipment and type of manufacturing. However, most process sheets include such information as description and numerical order of operations, manufacturing equipment used jigs, fixtures, tools and gauges used, speeds, feeds and depths of cut, material specifications, drawing specifications and revisions, if any.

Process Planning Activities :

Example 1 : A part drawing is shown in Fig. 2.2 (Gear shaft for water pump). The following are the activities / decisions involved in process planning.

1. Study and read the drawing so that the part features are identified. Theimportant feature of the part are:
   (a) Three concentric cylinders constitute the part.
   (b) There is one chamfer of 45° × 3 mm and one chamfer of 45° × 1.5 mm atthe ends of the shaft.
   (c) The dimensional tolerances are ± 0.05 mm and the angular tolerance on thechamfer is ± 1°. (*d*) Material is SAE 1030 cold drawn steel.
2. Only 5 pieces are required. The most feasible process is machining on a standardcentre lathe.
3. The parts can be machined from 25 mm diameter standard stock.
4. One lathe operator is required to complete the order.

5. The next step is to identify the operations. To produce the part the followingoperations are required: (*a*) Facing
   (*b*) Centre drilling(*c*) Cutting off (or) part off *d*) Turning
   (e) Chamfering
   (f) Finishing (removing sharp edges)



Material: 25 mm diameter SAE 1030 cold drawn steel
All Tolerances : ± 0.05 unless otherwise specifield
All dimensions are in mm. Number ofparts required : 5

Fig 2.2. Gear shaft forwater pump.

6. In addition, the process planner must estimate the time for each of these operations : the set-up time, the cutting tools needed, jigs, fixtures and gauges required, the machining parameters such as: Cutting speed, feed, d.o.c. (deptt of cut).
7. Completing the process planning sheet. The operations listed are sequenced in numerical order and are listed in the process sheet along with other necessary information. Fig. 2.3

Process Planning Sheet

Oper. No.	*Description of*	*Machine Name*	*Cutting Tool*	*Cutting (m/mi*	*rpm*	*Feed mm/re*	*Depth*	*Locating*	*Fixtures, Tools,*	*Remarks*
10	Face end	Centre lathe 7071	Facing tool	30	300	Hand	—	A	Use 25 mm lathe chuck	Use 3-jawed universal chuck
20	Center drill end	Centre lathe 7071	Combina-tion center	—	650	Hand	—	B		Cutting fluid or oil may
50	Cut off to				300	Hand	—	A		

90 100	Remove	Centre	File or		650	Hand	—	—		

No.	Revisions Schedule	Date	Part Identification
1	Added Oper. No. 100	18-1-06	Drawing No. : 76-10 GM, Stock No. : 48252
2			Part Name : Gear Shaft

Fig 2.3. A typical sample of an operation (process) analysis sheet used in manufacturing.

Machine Selection

Product manufacturing requires tools and machines that can produce economically as well as accurately. Economy depends to a large extent on the proper selection of the machine or process for the job that will give a satisfactory finished product. The selection of the machine is influenced, in turn by the quantity of items to be produced. Usually there is one machine best suited for a certain output.

In small lot or jobbing type manufacture, general purpose machines such as the lathe, drill press, and milling machine may prove to be the best type since they are adoptable, have lower initial cost, require less maintenance, and possess the flexibility to meet changing conditions in the shop.

However, a special purpose machine should be considered when large quantities of a standard product are to be produced. A machine built for one type of work or operation, such as the grinding of a piston or the machining of a cylinder head, will do the job well, quickly and at a low cost requiring only the service of a semi-skilled operator.

Many of the special-purpose machines or tools differ from the usual standard typein that they have built into them some of the skill of the operator. A simple bolt may be produced on either a lathe or an automatic screw machine. The lathe operator must not only know how to make the bolt but must also be sufficiently skilled to operate the lathe. On the automatic machine the sequence of operations and movements of tools are controlled by cams and stops, and each item produced is identical with the previous one. This “transfer of skill” into the machine makes possible the use of less skillfull operators, but it does requires greater skill in supervision and maintenance. Often it is not economical to make a machine completely automatic, as the cost may become prohibitive.

The selection of the best machine or process for a given product requires a knowledgeof all possible production methods. Factors that must be considered are:

(*a*) Volume of production (Quantity to be produced) *i.e.*, no. of components to be produced. (*b*) Quality of finished product, and

(*c*) Advantages and disadvantages of the various types of equipment capable of doing the work.

Too much emphasis cannot be given to the fact that production can be by several methods, but usually there is one way that is most economical.

Factors Influencing Process Selection

After a product design is made process selection is to be carried out. There areseveral factors which influence the process selection, These are :

1. Shape requirements
2. Size or dimensional requirements
3. Tolerance requirements
4. Surface finish requirements
5. Annual volume requirements (*i.e.*, production quantity required per annum)
6. Material characteristics.

Process selection requires a broad and extensive knowledge of various materials and the associated manufacturing processes. A good understanding of the capabilities and limitations of the various processes available is an asset to any process planner. Evaluation of alternative processes can also be carried out simultaneously and a logical decision takenwith respect to proper selection of the process.

It must be emphasized that the selection of a process is done and evaluated in the context of
product design - material - manufacturing process in an integrated manner.

Process Selection Parameters

There are several factors which govern the selection of a manufacturing process:

1. **Shape requirements of the final product *i.e.*, Geometric Form :** Geometric parameters such as solid shape, hollow shape, flat shape, flanged shape, concave shape, convex shape, cylindrical shape, presence of any part feartures such as groove, threaded shape, hole, chamfer, etc. are considered in the selection of a manufacturing process. Each process has its own capabilities and limitations with respect to the production of the above shapes and part features.
2. **Size or Dimensional requirements :** Some processes are capable of handling parts of small sizes and some processes can handle large sized parts economically and effectively.
3. **Tolerance requirements :** Each manufacturing process has got its own capability with regard to tolerance or accuracy of parts that can be produced using that process *e.g.* grinding process always gives close tolerances when compared with turning process. Depending upon the tolerance specified on the part drawing, suitable machining process is to be selected.
4. **Surface finish requirements :** Each manufacturing process has got its own capability with regard to the surface finish which it can provide on the part machined, *e.g.* reaming process can provide a better surface finish in a hole when compared with drilling process. Similarly cylindrical grinding give a better surface finish, than a plain turning process. Depending on the finish requirements specified on the component drawing, appropriate machining process need to be selected.
5. **Production volume requirements :** The economics of any machining process depends on the production volume, *i.e.*, no. of components required on a weekly, monthly or annual basis as the case may be. Existing order quantityas well as any anticipated future orders and their quantity need to be considered in the process selection. Some of the processes and additional cost incurred in the specialized toolings, jigs and fixtures can be justified only when there is a large volume of production.
6. **Material requirements :** The hardness, and strength characteristics of the material influence the tooling required. To machine hard and tough materials, carbide and ceramic tools are required. If slender or thin materials are machined, proper work holding devices and specially designed jigs and fixtures are required is order to avoid distortion and bending of work pieces during machining. Thus material requirements of the part also influence the appropriate selection of machining process.

SET OF DOCUMENTS REQUIRED FOR PROCESS PLANNING

(i) Product design and the engineering drawings pertaining to all the components of the product. (*i.e.*, components drawings, specifications and a bill of materials that defines how many of each component go into the product).

(ii) Machining/Machinability Data Handbook (Tables of cutting speeds, depth of cut,feeds for different processes and for different work materials).

(iii) Catalogues of various cutting tools and tool inserts.

(iv) Specifications of various machine tools available in the shop/catalogues of machine tools in the shop (speeds, feeds, capacity/power rating of motors, spindle size, table sizes etc.).

(v) Sizes of standard materials commercially available in
themarket. (*vi*) Machine Hr. cost of all equipment available
in the shop.

(vii) Design Data Handbook.

(viii) Charts of Limits, Fits & Tolerances.

(ix) Tables showing tolerances and surface finish obtainable for
differentmachining processes. (*x*) Tables of standard cost.

(xi) Table of allowances (such as Personal Allowance, Fatigue Allowance etc. in

%of standard time followed by the company).

(xii) Process plans of certain standard components such as shafts, bushings, flanges etc. (*xiii*) Handbooks (such as Tool Engineers Handbook, Design Data Handbook).

STEPS IN PROCESS PLANNING

(i) Required operations must be determined by examining the design data andemploying basic machining data such as :

(a) Holes can be made conveniently on drilling machines.

(b) Flat surfaces can be machined easily on millingmachines. (*c*) Cylindrical parts can be made using lathe.

Design data can be obtained from the part-drawing or from the finished partdesign file from the CAD system.

(ii) The machines required for each operation must be determined. This selection depends on knowledge of machine factors, such as availability of the machine, specifications of machine tools available in the shop, accuracy grade of the m/c, table size, spindle size, speed and feed ranges available, torque, power, machining rate and other size limitations.

(iii) The required tools for each identified machine or process must be determined. For selection of specialized tools knowledge and prior experience of process planner will be useful.

(iv) The optimum cutting parameters for each selected tool must be determined. These parameters include cutting speed, feed rate, depth of cut, and type of coolant/lubricant to be used. This determination depends on design data, such as work material, tool material, surface finish specifications and behaviour of cutting tool. Again expertise knowledge and prior experience of process planner and methods engineer will be useful in this regard. Machining data handbooks can also be referred.

(vi) Finally an optimum combination of these machining processes must be determined. The best process plan is the one which minimizes manufacturing time and cost. This provides a detailed plan for the economical manufacturingof the part.

The results of each of these five basic steps can be seen in the final form of the process plan.

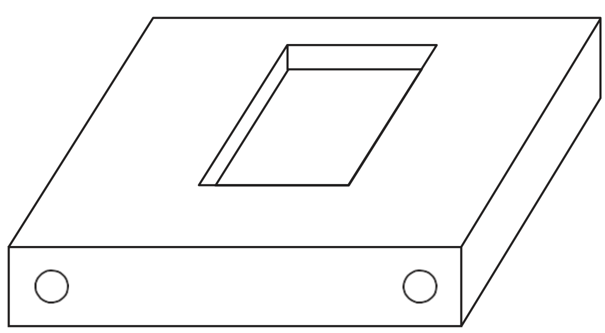


Fig. 2.4 (a) Part to be manufactured

Example 2 : Another example of a process plan for a part to be manufactured is shown below :

Machine : Vertical milling machine

Tool 1 : 150 mm dia. face mill

Operation 1 : Square to size 1000 mm × 1000 mm × 400 mm

Operation 2 : Finish mill to size : Tolerance + 0.03 mm

Tool 2 : 25 mm dia. Four-fluted end mill

Operation 1 : Mill pocket to 40.00 mm deep

Machine : Gun drilling machine

Tool 1 : 25 mm dia drill (850 mm long)

Operation 1 : Drill to 750 mm deep (2 holes)

Process plan

UNIT IV
PRODUCTION SCHEDULING

Introduction of Production Scheduling

Scheduling can be defined as "prescribing of when and where each operation necessary to manufacture the product is to be performed." It is also defined as "establishing of times at which to begin and complete each event or Operation comprising a procedure. The principle aim of scheduling is to plan the sequence of work so that production can be systematically arranged towards the end of completion of all products by due date.

Production Control Systems

An enterprise has a wide variety of functions. Its business activities are implementedby connecting one another for a better harmony with them, allowing it continue as a going concern. Generally, basic functions relating to the corporate activities are seen as systems, which are mainly categorized into the following five ones:

- Management system
- Selling system
- Production system
- Product distribution system
- Financial system

The production system can be said to consist of three systems

- Production control system (planning and administration divisions),
- Engineering system (engineeriing division), and
- Manufacturing system (manufacturing division).

Loading and scheduling-

Master Scheduling-

It was discussed in demand forecasting that in the dependent demand situation, if the demand for an item is known, the demand for other related items can be deduced. For example, if the demand of an automobile is known, the demand of its sub assemblies and sub components can easily be deduced. For dependent demand situations, normal reactive inventory control systems (i.e. EOQ etc.) are not suitable because they result in high inventory costs and unreliable delivery schedules. More recently, managers have realized that inventory planning systems (such as materials requirements planning) are better suited for dependent demand items. MRP is a simple system of calculating arithmetically the requirements of the input materials at different points of time based on actual production plan. MRP can also be defined as a planning and scheduling system to meet time-phased materials requirements for production operations. MRP always tries to meet the delivery schedule of end products as specified in the master production schedule.

MRP Objectives

MRP has several objectives, such as:

- **Reduction in Inventory Cost**: By providing the right quantity of material at right time to meet master production schedule, MRP tries to avoid the cost of excessive inventory.
- **Meeting Delivery Schedule**: By minimizing the delays in materials procurement, production decision making, MRP helps avoid delays in production thereby meeting delivery schedules more consistently.
- **Improved Performance**: By stream lining the production operations and minimizing the unplanned interruptions, MRP focuses on having all components available at right place in right quantity at right time.

MRP System

A simple sketch of an MRP system is shown in figure 1. It can be seen from the figure thatan MRP system has three major input components:

- **Master Production Schedule (MPS)**: MPS is designed to meet the market demand (both the firm orders and forecasted demand) in future in the taken planning horizon. MPS mainly depicts the detailed delivery schedule of the end products. However, orders for replacement components can also be included in it to make it more comprehensive.
- **Bill of Materials (BOM) File**: BOM represents the product structure. It encompasses information about all sub components needed, their quantity, and their sequence of buildup in the end product. Information about the work centers performing buildup operations is also included in it.
- **Inventory Status File**: Inventory status file keeps an up-to-date record of each itemin the inventory. Information such as, item identification number, quantity on hand,safety stock level, quantity already allocated and the procurement lead time of each item is recorded in this file.

Scheduling rules

- Work centers- The number of work centers in the shop must be specified.
- Job arrivals- The pattern and timing of jobs "arriving" at the facility must be specified.
- Job classification- The processing requirements or routing of jobs must be specified.
- Processing time- The time it takes to process jobs must be specified.
- Performance parameters-Any number of parameters that gauge the performance at the facility can be incorporated into the simulation; the quantification of these parameters must be specified. Options include percent idle time, amount of inventory, average lateness of jobs, average job flow, and so on.
- A Sequencing rule must be specified

Gantt charts & Perpetual loading-Basic scheduling problems Gantt Charts

Gantt charts and associated scheduling boards have been extensively used scheduling devices in the past, although many of the charts are now drawn by computer. Gantt charts are extremely easy to understand and can quickly reveal the current or planned situation to all concerned. They are used in several forms, namely,

(a) Scheduling or progress charts, which depicts the sequential schedule;

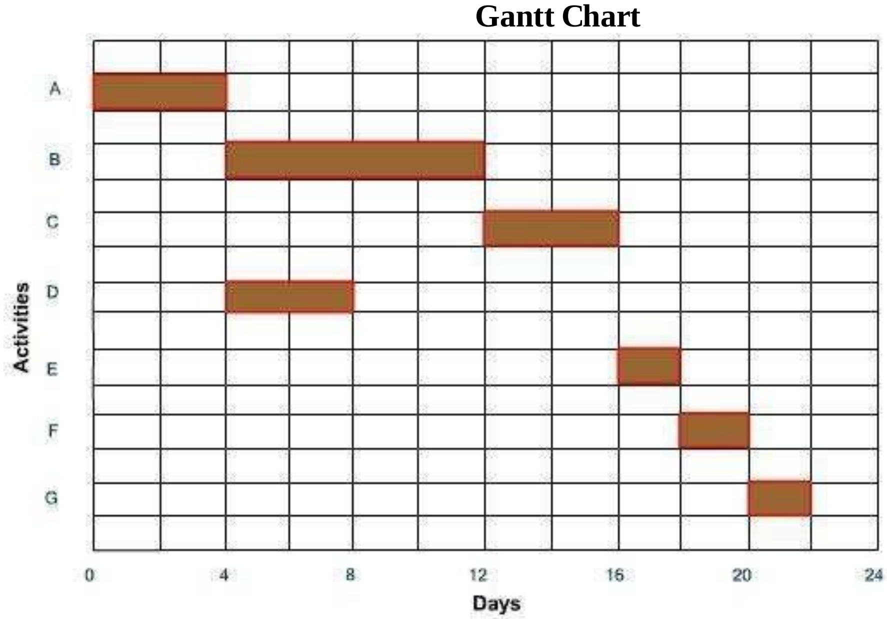
(b) Load charts, which show the work assigned to a group of workers or machines; and

(c) Record a chart, which are used to record the actual operating times anddelays of workers and machines.

Network Techniques

The network techniques of project management have developed in an evolutionary way in many years. Up to the end of 18^{th} century, the decision making in general and project management in particular was intuitive and depended primarily on managerial capabilities, experience, judgment and academic background of the managers. It was only in the early of 1900's that the pioneers of scientific management, started developing the scientific management techniques. The forerunner to network techniques, the Gantt chart was developed, during world war I, by Henry L Gantt, for the purpose of production scheduling. An example of Gantt chart is shown in Figure 1.

Figure1:
Gantt Chart



The Gantt chart was later modified to bar chart

Priority Decision Rules (Perpetualloading)

Priority decision rules are simplified guidelines for determining the sequence in which jobs will be done. In some firms these rules take the place of priority planning systems such as MRP systems. Following are some of the priority rules followed.

Symbol	*Priority rule*
FCFS	First come, first served
EDO	Earliest due date
LS	Least slack (that is, time due less processing
SPT	Shortest processing time
LPT	Longest processing time
PCO	Preferred customer order
RS	Random selection

Mathematical Programming Methods (Basic scheduling)

Scheduling is a complex resource allocation problem. Firms process capacity, labour skills, materials and they seek to allocate their use so as to maximize a profit or service objective, or perhaps meet a demand while minimizing costs.

The following are some of the models used in scheduling problems and production control.

(a) **Linear programming model:** Here all the constraints and objective functions are formulated as a linear equation and then problem is solved for optimality. *Simplex method, transportation methods* and *assignment method* are major methods used here.

(b) **PERT/CPM network model:** PERT/CPM network is the network showing the sequence of operations for a project and the precedence relation between the activitiesto be completed.

Basic scheduling problems

Scheduling Strategies

Scheduling strategies vary widely among firms and range from 'no scheduling' to very sophisticated approaches.

These strategies are grouped into four classes:

1. **Detailed scheduling:** Detailed scheduling for specific jobs that are arrived from customers is impracticable in actual manufacturing situation. Changes in orders, equipment breakdown, and unforeseen events deviate the plans.
2. **Cumulative scheduling:** Cumulative scheduling of total work load is useful especially for long range planning of capacity needs. This may load the current period excessivelyand under load future periods. It has some means to control the jobs.
3. **Cumulative detailed:** Cumulative detailed combination is both feasible and practical approach. If master schedule has fixed and flexible portions.
4. **Priority decision rules:** Priority decision rules are scheduling guides that are used

independently and in conjunction with one of the above strategies, *i.e.*, first come first serve. These are useful in reducing Work-In-Process (WIP) inventory.

Inputs to Scheduling

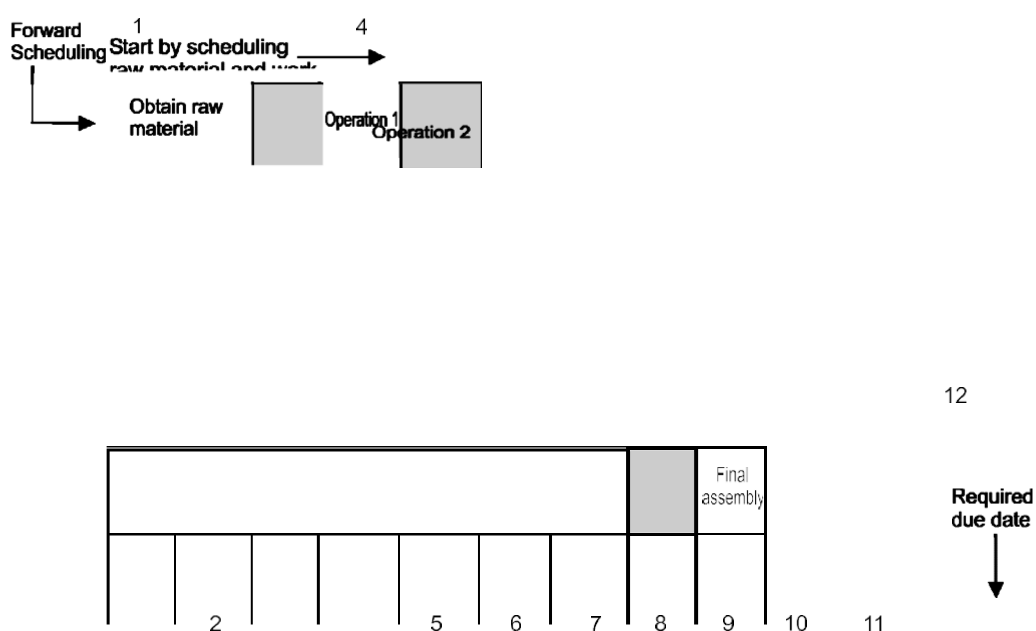
1. *Performance standards:* The information regarding the performance standards (standard times for operations) helps to know the capacity in order to assign required machine hours to the facility.
2. Units in which loading and scheduling is to be expressed.
3. Effective capacity of the work centre.
4. Demand pattern and extent of flexibility to be provided for rush orders.
5. Overlapping of operations.
6. Individual job schedules.

Types of Scheduling

Types of scheduling can be categorized as forward scheduling and backward scheduling.

1. **Forward scheduling** is commonly used in job shops where customers place their orders on “needed as soon as possible” basis. Forward scheduling determines start and finish times of next priority job by assigning it the earliest available time slot and from that time, determines when the job will be finished in that work centre. Since the job and its components start as early as possible, they will typically be completed before they are due at the subsequent work centres in the routing. The forward method generates in the process inventory that are needed at subsequent work centres and higher inventory cost. Forward scheduling is simple to use and it gets jobs done in shorter lead times, compared to backward scheduling.

2. **Backward scheduling** is often used in assembly type industries and commit in advance to specific delivery dates. Backward scheduling determines the start and finish times for waiting jobs by assigning them to the latest available time slot that will enable each job to be completed just when it is due, but done before. By assigning jobs as lateas possible, backward scheduling minimizes inventories since a job is not completed until it must go directly to the next work centre on its routing. Forward and backward scheduling methods are shown in Fig. 5.7.



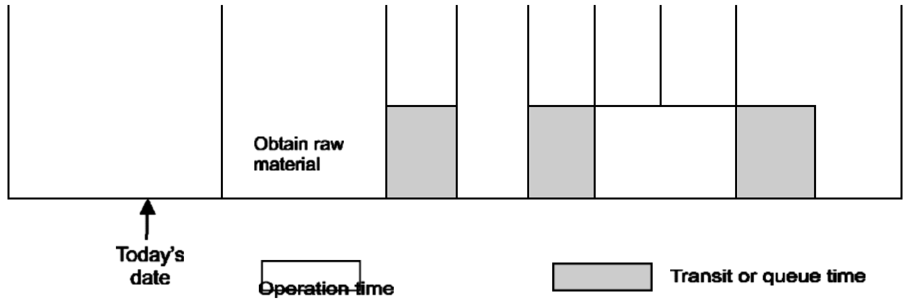


Fig. 5.7 *Forward and backward scheduling*

Line of balance & Flow production scheduling

Line-balancing strategy is to make production lines flexible enough to absorb external and internal irregularities. There are two types of line balancing, which we have explained as –

- Static Balance – Refers to long-term differences in capacity over a period of several hours or longer. Static imbalance results in underutilization of workstations, machines and people.
- Dynamic Balance – Refers to short-term differences in capacity, like, over a period of minutes, hours at most. Dynamic imbalance arises from product mix changes and variations in work time unrelated to product mix.

Flow production scheduling (Principles of Scheduling)

1. **The principle of optimum task size:** Scheduling tends to achieve maximum efficiency when the task sizes are small, and all tasks of same order of magnitude.
2. **Principle of optimum production plan:** The planning should be such that it imposes an equal load on all plants.
3. **Principle of optimum sequence:** Scheduling tends to achieve the maximum efficiency when the work is planned so that work hours are normally used in the same sequence.

Batch production scheduling-

Batch production scheduling

Background

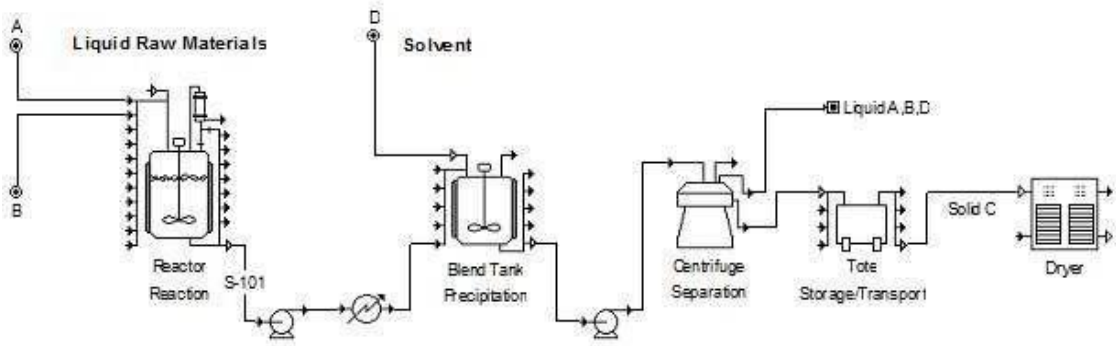
Batch production scheduling is the practice of planning and scheduling of batch manufacturing processes. See Batch production. Although scheduling may apply to traditionally continuous processes such as refining, it is especially important for batch processes such as those for pharmaceutical active ingredients, biotechnology processes and many specialty chemical processes. Batch production scheduling shares some concepts and techniques with finite capacity scheduling which has been applied to many manufacturing problems. The specific issues of scheduling batch manufacturing processes have generated considerable industrial and academic interest.

Scheduling in the batch processing environment

A batch process can be described in terms of a recipe which comprises a bill of materials and operating instructions which describe how to make the product. The ISA S88 batch process control standard provides a framework for describing a batch process recipe. The standard provides a procedural hierarchy for a recipe. A recipe may be organized into a series of unit-procedures or major steps. Unit-procedures are organized into operations, and operations may be further organized into phases.

The following text-book recipe illustrates the organization.

- Charge and Mix materials A and B in a heated reactor, heat to 80C and react 4 hours to form C.
- Transfer to blending tank, add solvent D, Blend 1hour. Solid C precipitates.
- Centrifuge for 2 hours to separate C.
- Dry in a tray dryer for 1 hour.



A simplified S88-style procedural organization of the recipe might appear as follows:

- **Unit Procedure 1: Reaction**
    - Operation 1: Charge A & B (0.5 hours)
    - Operation 2: Blend / Heat (1 hour)
    - Operation 3: Hold at 80C for 4 hours
    - Operation 4: Pump solution through cooler to blend tank (0.5 hours)
    - Operation 5: Clean (1 hour)
- **Unit Procedure 2: Blending Precipitation**
    - Operation 1: Receive solution from reactor
    - Operation 2: Add solvent, D (0.5 hours)
    - Operation 3: Blend for 2 hours
    - Operation 4: Pump to centrifuge for 2 hours
    - Operation 5: Clean up (1 hour)
- **Unit Procedure 3: Centrifugation**
    - Operation 1: Centrifuge solution for 2 hours
    - Operation 2: Clean
- **Unit Procedure 4: Tote**
    - Operation 1: Receive material from centrifuge
    - Operation 2: Load dryer (15 min)
- **Unit Procedure 5: Dry**
    - Operation 1: Load
    - Operation 2: Dry (1 hour)

Note that the organization here is intended to capture the entire process for scheduling. A recipe for process-control purposes may have a more narrow scope.

In addition to process equipment, batch process activities may require labor, materials,utilities and extra equipment.

Product sequencing

Use the Intelligent sequencing feature to add conditions to help sort your product sequence. The conditions are a set of metrics you can choose from to help you achieve your business goals.

IBM Digital Analytics Product Sequencing rules

Table 1. IBM Digital Analytics Product Sequencing rules

IBM Digital Analytics metric name	**Metric description**
Item Sales	Total sales revenue of items.
Items Sold	The number of items (units) sold.
Product Views	The total number of times that the product details page for this product was viewed. This metric is a count of the collected Product View analytics tags.
Item Abandonment Rate	The ratio of the number of items that were abandoned to the number of items that were placed in a shopping cart.(Items Abandoned / Items Added)
Items Added	The number of items that were placed into a shopping cart. Adding items to a cart does not necessarily mean that the items were purchased.
Margin	Margin is calculated as (average item price - product cost) / average item price, expressed as a percentage.

Production Control systems & Periodic batch control-A

Production Control System in Perspective

An enterprise has a wide variety of functions. Its business activities are implemented by connecting one another for a better harmony with them, allowing it continue as a going concern. Generally, basic functions relating to the corporate activities are seen as systems, which are mainly categorized into the following five ones:

- Management system
  The system performs the corporate control and governance so that each function the enterprise has can work harmoniously with each other. The main mission is to manage human resources, and to draw up management structure plans as well as business plans indispensable for its future development.
- Selling system
  The system mainly performs market researches, management of the company's customers and distributors, its inventory control, and its order management in order to improve customer service, expand its market share , and increase its sales volume.
- Production system
  The system makes an effective use of production materials of human resources, raw materials and facilities to perform the engineering, purchasing, and producing activities so that it can produce adequate products to meet certain conditions (in quantity and delivery time) at the lowest cost.
- Product distribution system
  The system functions as a supplementary means in such activities as product positioning, sales promotion, and product distribution, and performs various activities including packing, loading/unloading, shipping, storing and communications, in order to supply more adequate products to the company'scustomers.
- Financial system
  The system controls and governs the activities of obtaining and utilizing the company's capital in order to facilitate its business activities over the long or short term.

Periodic batch control

Recently, the production system of manufacturing companies have been functionally fragmented in a remarkable manner, in accordance with rapid technological innovation. Such fragmentation has been notably seen in the engineering and producing fields. In other words, the production system can be said to consist of three systems: production control system (planning and administration divisions), engineering system (engineeriing division), and manufacturing system (manufacturing division).

- Production control system
  The system performs planning and management activities to make the effective use of human resources, raw materials, and facilities based on the order information received from customers.
- Engineering system

The system uses computers to engineer manufacturing technologies and processes as well as products according to customers' specifications. It is commonly called CAD/CAM system (Computer Aided Design/Computer Aided Manufacturing System).

- Manufacturing system

  The system automatically uses automatic machine tools, robots, etc. to perform processing and assembly operations in response to the production schedule information and manufacturing technology information received from production control system and engineering system, respectively. This is an automation systemfor high-mix low-volume manufacturing, commonly called FMS (Flexible Manufacturing System).

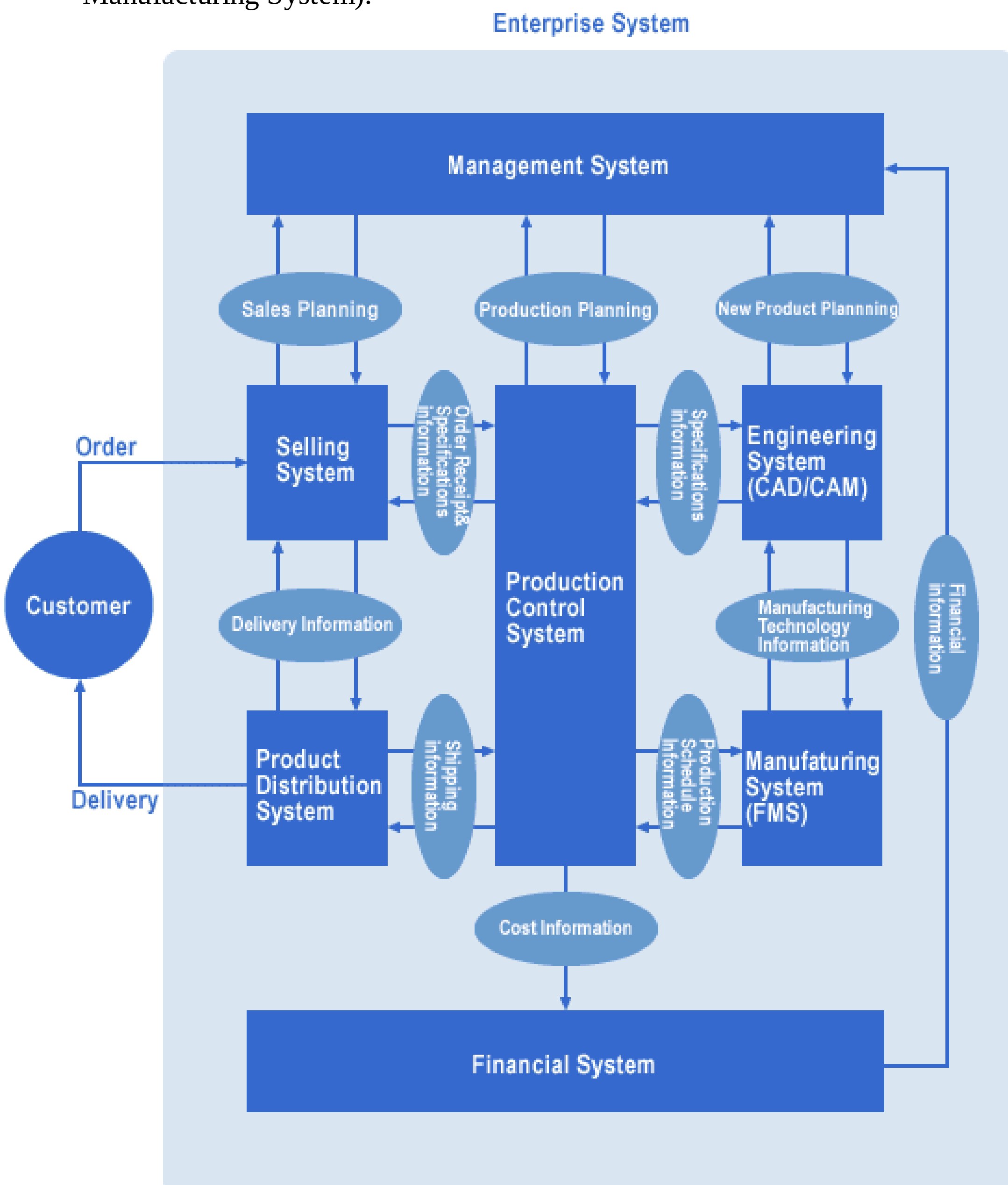


FIG. 1: How a production control system works in an enterprise system

When an enterprise is seen as a large system, each function which works individually as a basic function in the enterprise's activities relates to each other as depicted in the FIG. 1.

Material requirement planning kanban – Dispatching

Kanban (カンバン?), literally meaning "signboard" or "billboard", is a concept related tolean and just-in-time (JIT) production. According to its creator, Taiichi Ohno, Kanban is one means through which JIT is achieved.Kanban is not an inventory control system. It is a scheduling system that helps determine what to produce, when to produce it, and how much to produce. The need to maintain a high rate of improvement led Toyota to devise the Kanban system. Kanban became an effective tool to support the running ofthe production system as a whole. In addition, it proved to be an excellent way for promoting improvements because reducing the number of Kanban in circulation highlightedproblem areas

MRP

Material requirements planning (MRP) is a production planning and inventory contro lsystem used to manage manufacturing processes. Most MRP systems are software- based, while it is possible to conduct MRP by hand as well.An MRP system is intended to simultaneously meet three objectives:

- Ensure materials are available for production and products are available for deliveryto customers.
- Maintain the lowest possible material and product levels in store
- Plan manufacturing activities, delivery schedules and purchasing activities

OBJECTIVE

Briefly discussing on Kanban and MRP of their system and hence differentiate which isthe better system for operation management

KANBAN Versus MRP

In conventional MRP procedures, production quantities and dates are calculated in accordance with actual customer/planned independent requirements and the required quantity and dates of the components are calculated by exploding the bill of material. The production quantities can be compiled for various requirements. The creation of lot sizes is based on the selected lot sizing procedure. In each production level, the lots are usually produced completely before being passed on for further processing. The dates calculated in MRP are the results of adetailed planning run for the current production level even if it isnot known exactly when the material is required for the subsequent production level at the time of the planning run. The material is pushed through production on the basis of these dates (PUSH PRINCIPLE). This often leads to queue times before production can be started or until the material can be processed further. These queue times are planned as increased lead times or floats in planning and are rarely undercut. This results in high inventoryand longer lead times in production.

DESPATCHING

In KANBAN techniques no separate, higher-level planning is used to control the material flow through production. Instead, the work center further down the line (demand source)requests material from the preceding work center (supply source) only when it is required (PULLPRINCIPLE). For this purpose, a control cycle is created - with a fixed number of kanbans(cards) - between the supply source and the demand source. Each kanbanrepresents a specific material quantity and usually represents a container (however, this need not be the case). When the material quantity of a kanban has been consumed, it is given the status EMPTY and is sent to the supply source. The kanban is the signal for the supply source to go ahead and produce the quantity of material recorded on the kanban. Once production is complete, the material is delivered to the demand source which confirms the receipt of the material by setting the status back to FULL. The lot size is determined by the kanbans and this quantity is produced by the supply source in one run. The total production quantity is calculated by the total number of kanbans sent to the supply source within a predefined period. Replenishment frequency is based on actual consumption. This means that if more material is required, the kanbans simply circulate between the supply source and the demand source more quickly. If less material is required, the kanbans circulate more slowly. If no material is required, then all the kanbans will remain at the demand source with the material, meaning that all of the components required to start producing the corresponding assembly are available. There is never more material in circulation than is defined by the number of kanbans in the control cycle and all of the production levels that are controlled using KANBAN techniques are always in a position to start production.

Progress reporting and expediting-Manufacturing lead time

EXPEDITING

Expediting is a concept in purchasing and project management for securing the quality and timely delivery of goods and components.

The procurement department or an external expeditor controls the progress of manufacturing at the supplier concerning quality, packing, conformity with standards and set timelines. Thus the expeditor makes sure that the required goods arrive at the appointed date in the agreed quality at the agreed location.

Expediting exists in several levels:

- Production control: The expeditor inspects the factory whether the production is upto the standards of the country the goods are destined for. This is especially necessary for food or engineering equipment like power plant components. He or she controls as well whether the regular audits for ISO 9001 etc. have been made.
- Quality control: The components are tested whether they function as required and whether they are made to the measurements and standards of the customer. A part of this quality control can be the testing for compliance with standards of the destination country, e.g. ASME.
- Packing/transport survey: This is the lowest and most used level of expediting, as the goods are only counted and the packing is controlled whether it will withstand the adversities of transport (pre-shipment inspection).
- Project management: At a large-scale project, not only goods are controlled. The expeditor also keeps an eye on the deadlines and milestones of the project and whether the supplier will be on time. This way he or she monitors the crucial procurement parts of the project.

As the different levels of expediting require different skills, specialists and laboratories, many third party expeditors specialize in only one or several of these levels, while few offer expediting services on all levels.

Field expediting

Field expediting provides clients with a comprehensive review of the precise standing of their order and any on site action to rectify any potential problem areas. Field expediting means the inspection and control of the expeditor on site. This gives clients a comprehensive review of the exact current status of their order and an educated projection of the future planning and status. Furthermore, while being on site, experts for expediting can identify possible problems and bottlenecks that could lead to potential delays.

Desk expediting

Desk expediting is also known as telephone expediting. It is an important tool for producing companies to monitor order progress with manufacturers. Especially at milestone of a project, desk expediting can be helpful to check whether the project is still within the agreed schedule. Although desk expediting is a quick and easy way to be informed about thecurrent status of a project, it should always be conducted in combination with field expediting to securely verify the actual status.

Phone expediting

Desk/Phone expediting provides a valuable tool for monitoring the progress of orders with a manufacturer. Contact is established at specific milestones within the order fabrication method and a brief outline of status standing obtained throughout the following conversation. associate experienced expeditor will very quickly assess whether the order is progressing consistent with plan or whether alternative measures are needed to verify and presumably improve the order progress. desk / phone expediting is best used as a tool to supplement field expediting. it's additionally a helpful approach of making the vendor aware that delays on the order won't be accepted by their shopper.

MANUFACTURING LEAD TIME

A lead time is the latency between the initiation and execution of a process. For example, the lead time between the placement of an order and delivery of a new car from a manufacturer may be anywhere from 2 weeks to 6 months. In industry, lead time reduction

is an important part of lean manufacturing and lean construction

In the manufacturing environment, lead time has the same definition as that of Supply Chain Management, but it includes the time required to ship the parts from the supplier. The shipping time is included because the manufacturing company needs to know when theparts will be available for material requirements planning. It is also possible for lead time to include the time it takes for a company to process and have the part ready for manufacturing once it has been received. The time it takes a company to unload a product from a truck, inspect it, and move it into storage is non-trivial. With tight manufacturing constraints or when a company is using Just In Time manufacturing it is important for supply chain to know how long their own internal processes take.

Lead time is made of:

- **Preprocessing Lead Time** (also known as "planning time" or "paperwork"): It represents the time required to release a purchase order (if you buy an item) or create a job (if you manufacture an item) from the time you learn of the requirement.
- **Processing Lead Time**: It is the time required to procure or manufacture an item.
- **Postprocessing Lead Time**: It represents the time to make a purchased item available in inventory from the time you receive it (including quarantine, inspection, etc.)

Example

Company A needs a part that can be manufactured in two days once Company B has received an order. It takes three days for company A to receive the part once shipped, and one additional day before the part is ready to go into manufacturing.

- If Company A's Supply Chain calls Company B they will be quoted a lead time of 2 days for the part.
- If Company A's Manufacturing division asks the Supply Chain division what the lead time is, they will be quoted 5 days since shipping will be included.
- If a line worker asks the Manufacturing Division boss what the lead time is beforethe part is ready to be used, it will be 6 days because setup time will be included.

In more detail

Lead Time terminology has been defined in greater detail.[4] The Supply Chain from customer order received to the moment the order is delivered is divided into five lead times.

- **Order Lead Time** - Time from customer order received to customer order delivered.
- **Order Handling Time** - Time from customer order received to sales order created.
- **Manufacturing Lead Time** - Time from sales order created to production finished (ready for delivery).
- **Production Lead Time** - Time from start of physical production of first submodule/part to production finished (ready for delivery).

Delivery Lead Time - Time from production finished to customer order delivered

Techniques for aligning completion times and due dates.

Aligning Completion Times

Time a job is completed minus the time the job was first available for processing; avg.flow time measures responsiveness

1. Decide which priority rule to use
2. List all jobs waiting to be processed with their job time
3. Using priority rule determine which job has highest priority then second, third and so on

- First come, first served (FCFS)
- Last come, first served (LCFS)
- Earliest due date (EDD)
- Shortest processing time (SPT)
- Longest processing time (LPT)
- Critical ratio (CR):
  - (Time until due date)/(processing time)
- Slack per remaining Operations (S/RO)
  - Slack /(number of remaining operations)

Calculation of completion time and Due date:

- Calculation mean flow time:
  - MFT= (sum job flow times)/ # of jobs
  - = (10+13+17+20)/4 = 60/4 = 15 days

- Calculating average number of jobs in the system:
    - Average # Jobs =(sum job flow times)/ # days to complete batch
        - = (60)/20 = 3 job
- Makespan is the length of time to complete a batch
    - Makespan = Completion time for Job D minus start time for Job A
        - = 20 – 0 = 20 days

UNIT V

INVENTORY CONTROL AND RECENT TRENDS IN PPC

Introduction of Inventory Control (InventoryFundamentals)

Inventories are materials and supplies that a business or institution carries either for sale or to provide inputs or supplies to the production process. All businesses and institutions require inventories. Often they are a substantial part of total assets.

Financially, inventories are very important to manufacturing companies. On the balance sheet, they usually represent from 20% to 60% of total assets. As inventories are used, their value is converted into cash, which improves cash flow and return on investment. There is a cost for carrying inventories, which increases operating costs and decreases profits. Good inventory management is essential.

Inventory management is responsible for planning and controlling inventory from the raw material stage to the customer. Since inventory either results from production or supports it, the two cannot be managed separately and, therefore, must be coordinated. Inventory must be considered at each of the planning levels and is thus part of production planning, master production scheduling, and material require- ments planning. Production planning is concerned with overall inventory, master planning with end items, and material requirements planning with component parts and raw material.

Inventory control (Management)

AGGREGATE INVENTORY MANAGEMENT

Aggregate inventory management deals with managing inventories according to their classification (raw material, work-in-process, and finished goods) and the function they perform rather than at the individual item level. It is financially oriented and is concerned with the costs and benefits of carrying the different classifications of inven- tories. As such, aggregate inventory management involves:

- Flow and kinds of inventory needed.
- Supply and demand patterns.
- Functions that inventories perform.
- Objectives of inventory management.
- Costs associated with inventories.

ITEM INVENTORY MANAGEMENT

Inventory is not only managed at the aggregate level but also at the item level. Management must establish decision rules about inventory items so the staff responsi-ble for inventory control can do their job effectively. These rules include the following:

- Which individual inventory items are most important.
- How individual items are to be controlled.
- How much to order at one time.
- When to place an order.

This chapter will study aggregate inventory management and somefactors influencing inventory management decisions, which include:

- Types of inventory based on the flow of material.

- Supply and demand patterns.
- Functions performed by inventory.
- Objectives of inventory management.
- Inventory costs.

Finally, this chapter will conclude with a study of the first two decisions, decid- ing the importance of individual end items and how they are controlled. Subsequent chapters will discuss the question of how much stock to order at one time and when toplace orders.

INVENTORY AND THE FLOW OF MATERIAL

There are many ways to classify inventories. One often-used classification is related tothe flow of materials into, through, and out of a manufacturing organization.

- **Raw materials**. These are purchased items received that have not entered the production process. They include purchased materials, component parts, and subassemblies.
- **Work-in-process (WIP)**. Raw materials that have entered the manufacturing process and are being worked on or waiting to be worked on.
- **Finished goods**. The finished products of the production process that are ready to be sold as completed items. They may be held at a factory or central ware- house or at various points in the distribution system.
- **Distribution inventories**. Finished goods located in the distribution system.
- **Maintenance, repair, and operational supplies (MROs)**. Items used in produc- tion that do not become part of the product. These include hand tools, spare parts, lubricants, and cleaning supplies.

Classification of an item into a particular inventory depends on the production environment. For instance, sheet steel or tires are finished goods to the supplier but are raw materials and component parts to the car manufacturer.

SUPPLY AND DEMAND PATTERNS

If supply met demand exactly, there would be little need for inventory. Goods could be made at the same rate as demand, and no inventory would build up. For this situa- tion to exist, demand must be predictable, stable, and relatively constant over a long time period.

If this is so, manufacturing can produce goods on a line-flow basis, matching production to demand. Using this system, raw materials are fed to production as required, work flow from one workstation to another is balanced so little work-in-process inventory is required, and goods are delivered to the customer at the rate the customer needs them. Flow manufacturing systems were discussed in Chapter 1. Because the variety of products they can make is so limited, demand has to be large enough to justify economically setting up the system. These systems are characteristic of just-in-time manufacturing and will be discussed in Chapter 15.

Demand for most products is neither sufficient nor constant enough to warrant setting up a line-flow system, and these products are usually made in lots or batches. Workstations are organized by function—for example, all machine tools in one area, all welding in another, and assembly in another. Work moves in lots from one work- station to another as required by the routing. By the nature of the system, inventory will build up in raw materials, work-in-process, and finished goods.

Purpose of holding stock (Methods)

FUNCTIONS OF INVENTORIES

In batch manufacturing, the basic purpose of inventories is to decouplesupply and demand. Inventory serves as a buffer between:

- Supply and demand.
- Customer demand and finished goods.
- Finished goods and component availability.
- Requirements for an operation and the output from the preceding operation.

Anticipation Inventory

Anticipation inventories are built up in anticipation of future demand. For example, they are created ahead of a peak selling season, a promotion program, vacation shut- down, or possibly the threat of a strike. They are built up to help level production and to reduce the costs of changing production rates.

Fluctuation Inventory (Safety Stock)

Fluctuation inventory is held to cover random unpredictable fluctuations in supply and demand or lead time. If demand or lead time is greater than forecast, a stockout will occur. **Safety stock** is carried to protect against this possibility. Its purpose is to prevent disruptions in manufacturing or deliveries to customers. Safety stock is also called buffer stock or reserve stock.

Lot-Size Inventory

Items purchased or manufactured in quantities greater than needed immediately cre- ate **lot-size inventories**. This is to take advantage of quantity discounts; to reduce shipping, clerical, and setup costs; and in cases where it is impossible to make or pur- chase items at the same rate that they will be used or sold. Lot-size inventory is some- times called**cycle stock**.

It is the portion of inventory that depletes gradually as cus- tomers' orders come in and is replenished cyclically when suppliers' orders are received.

Transportation Inventory

Transportation inventories exist because of the time needed to move goods from one location to another such as from a plant to a distribution center or a customer. They are sometimes called **pipeline** or **movement inventories**. The average amount of inventory in transit is:

$$I = \frac{tA}{365}$$

where I is the average annual inventory in transit, t is transit time in days, and A is annual demand. Notice that the transit inventory does not depend upon the shipment size but on the transit time and the annual demand. The only way to reduce the inven- tory in transit, and its cost, is to reduce the transit time.

Hedge Inventory

Some products such as minerals and commodities—for example, grains or animal products—are traded on a worldwide market. The price for these products fluctuates according to world supply and demand. If buyers expect prices to rise, they can pur- chase **hedge inventory** when prices are low.

Hedging is complex and beyond the scope of this text.

Maintenance, Repair, and Operating Supplies (MROs)

MROs are items used to support general operations and maintenance but that do not become directly part of a product. They include maintenance supplies, spare parts, and consumables such as cleaning compounds, lubricants, pencils, and erasers.

OBJECTIVES OF INVENTORY MANAGEMENT

A firm wishing to maximize profit will have at least the following objectives:

- Maximum customer service.
- Low-cost plant operation.
- Minimum inventory investment.

Effect of demand on inventories (Methods)

Customer Service

In broad terms, customer service is the ability of a company to satisfy the needs of customers. In inventory management, the term is used to describe the availability of items when needed and is a measure of inventory management effectiveness. The customer can be a purchaser, a distributor, another plant in the organization, or the workstation where the next operation is to be performed.

There are many different ways to measure customer service, each with its strengths and weaknesses, but there is no one best measurement. Some measures are percentage of orders shipped on schedule, percentage of line items shipped on sched- ule, and order-days out of stock.

Inventories help to maximize customer service by protecting against uncer- tainty. If we could forecast exactly what customers want and when, we could plan to meet demand with no uncertainty. However, demand and the lead time to get an item are often uncertain, possibly resulting in stockouts and customer dissatisfaction. For these reasons, it may be necessary to carry extra inventory to protect against uncer- tainty. This inventory is called safety stock and will be discussed in operating Efficiency

Inventories help make a manufacturing operation more productive in four ways:.

1. Inventories allow operations with different rates of production to operate sepa- rately and more economically. If two or more operations in a sequence have dif- ferent rates of output and are to be operated efficiently, inventories must build up between them.

2. Chapter 2 discussed production planning for seasonal products in which demand is nonuniform throughout the year. One strategy discussed was to level production and build anticipation inventory for sale in the peak periods. This wouldresult in the following:
   - Lower overtime costs.
   - Lower hiring and firing costs.
   - Lower training costs.
   - Lower subcontracting costs.

- Lower capacity required.

By leveling production, manufacturing can continually produce an amount equalto the average demand. The advantage of this strategy is that the costs of changing production levels are avoided. Figure 9.2 shows this strategy.

3. Inventories allow manufacturing to run longer production runs, which result inthe following:
   - *Lower setup costs per item.* The cost to make a lot or batch depends upon the setup costs and the run costs. The setup costs are fixed, but the run costs vary with the number produced. If larger lots are run, the setup costs are absorbed over a larger number, and the average (unit) cost is lower.
   - *An increase in production capacity due to production resources being used at a greater portion of the time for processing as opposed to setup.*

     Time on a work center is taken up by setup and by run-time. Output occurs only when an item is being worked on and not when setup is taking place. If larger quanti- ties are produced at one time, there are fewer setups required to produce a given annual output, and thus more time is available for producing goods. This is most important with bottleneck resources. Time lost on setup on these resources is lost throughput (total production) and lost capacity.
4. Inventories allow manufacturing to purchase in larger quantities, which results in lower ordering costs per unit and quantity discounts.

But all of this is at a price. The problem is to balance inventory investment with the following:

1. *Customer service.* The lower the inventory, the higher the likelihood of a stock- out and the lower the level of customer service. The higher the inventory level, the higher customer service will be.

2. *Costs associated with changing production levels.* Excess equipment capacity, overtime, hiring, training, and layoff costs will all be higher if production fluctu- ates with demand.

3. *Cost of placing orders.* Lower inventories can be achieved by ordering smaller quantities more often, but this practice results in higher annual ordering costs.

4. *Transportation costs.* Goods moved in small quantities cost more to move per unit than those moved in large quantities. However, moving large lots implies higher inventory.

If inventory is carried, there has to be a benefit that exceeds the costs of carry- ing that inventory. Someone once said that the only good reason for carrying inven- tory beyond current needs is if it costs less to carry it than not. This being so, we should turn our attention to the costs associated with inventory.

INVENTORY COSTS

The following costs are used for inventory management decisions:

- Item cost.
- Carrying costs.
- Ordering costs.
- Stockout costs.
- Capacity-associated costs.

Item cost is the price paid for a purchased item, which consists of the cost of the item and any other direct costs associated in getting the item into the plant. These could include such things as transportation, custom duties, and insurance. The inclusive

cost is often called the **landed price**. For an item manufactured in-house, the cost includes direct material, direct labor, and factory overhead. These costs can usually be obtained from either purchasing or accounting.

Carrying costs include all expenses incurred by the firm because of the volume of inventory carried. As inventory increases, so do these costs. They can be broken down into three categories:

1. *Capital costs.* Money invested in inventory is not available for other uses and as such represents a lost opportunity cost. The minimum cost would be the inter- est lost by not investing the money at the prevailing interest rate, and it may be much higher depending on investment opportunities for the firm.

2. *Storage costs.* Storing inventory requires space, workers, and equipment. As inventory increases, so do these costs.

3. *Risk costs.* The risks in carrying inventory are:

a. Obsolescence; loss of product value resulting from a model or style change or technological development.

b. Damage; inventory damaged while being held or moved.

c. Pilferage; goods lost, strayed, or stolen.

d. Deterioration; inventory that rots or dissipates in storage or whose shelf life is limited.

What does it cost to carry inventory? Actual figures vary from industry to indus- try and company to company. Capital costs may vary depending upon interest rates, the credit rating of the firm, and the opportunities the firm may have for investment. Storage costs vary with location and type of storage needed. Risk costs can be very low or can be close to 100% of the value of the item for perishable goods. The carry- ing cost is usually defined as a percentage of the dollar value of inventory per unit of time (usually one year). Textbooks tend to use a figure of 20–30% in manufacturing industries. This is realistic in many cases but not with all products. For example, the possibility of obsolescence with fad or fashion items is high, and the cost of carrying such items is greater.

Ordering procedures. Two bin system

Ordering Costs

Ordering costs are those costs associated with placing an order either with the factory or a supplier. The cost of placing an order does not depend upon the quantity ordered. Whether a lot of 10 or 100 is ordered, the costs associated with placing the order are essentially the same. However, the annual cost of ordering depends upon the number of orders placed in a year.

Ordering costs in a factory include the following:

- *Production control costs.* The annual cost and effort expended in production control depends on the number of orders placed, not on the quantity ordered. The fewer orders per year, the less cost. The costs incurred are those of issuing and closing orders, scheduling, loading, dispatching, and expediting.
- *Setup and teardown costs.* Every time an order is issued, work centers have toset up to run the order and tear down the setup at the end of the run. These costsdo not

depend upon the quantity ordered but on the number of orders placed peryear.

- *Lost capacity cost.* Every time an order is placed at a work center, the time taken to set up is lost as productive output time. This represents a loss of capacity and is directly related to the number of orders placed. It is particularly important and costly with bottleneck work centers.
- *Purchase order cost.* Every time a purchase order is placed, costs are incurred to place the order. These costs include order preparation, follow-up, expediting, receiving, authorizing payment, and the accounting cost of receiving and paying the invoice.

The annual cost of ordering depends upon the number of orders placed in a year. This can be reduced by ordering more at one time, resulting in the placing of fewer orders. However, this drives up the inventory level and the annual cost of car- rying inventory.

Stockout Costs

If demand during the lead time exceeds forecast, we can expect a **stockout**. A stock- out can potentially be expensive because of back-order costs, lost sales, and possibly lost customers. Stockouts can be reduced by carrying extra inventory to protect against those times when the demand during lead time is greater than forecast.

Capacity-Associated Costs

When output levels must be changed, there may be costs for overtime, hiring, train- ing, extra shifts, and layoffs. These **capacity-associated costs** can be avoided by level- ing production, that is, by producing items in slack periods for sale in peak periods. However, this builds inventory in theslack periods.

FINANCIAL STATEMENTS AND INVENTORY

The two major financial statements are the balance sheet and the income state- ment. The balance sheet shows assets, liabilities, and owners' equity. The income statement shows the revenues made and the expenses incurred in achieving that revenue.

Balance Sheet

An **asset** is something that has value and is expected to benefit the future operation of the business. An asset may be tangible, such as cash, inventory, machinery, and buildings, or may be intangible, such as accounts receivable or a patent.

Liabilities are obligations or amounts owed by a company. Accounts payable, wages payable, and long-term debt are examples of liabilities.

Owners' equity is the difference between assets and liabilities. After all the lia- bilities are paid, it represents what is left for the owners of the business. Owners' equity is created either by the owners investing money in the business or through the operation of the business when it earns a profit. It is decreased when owners take money out of the business or when the business loses money. The **accounting equation.** The relationship between assets,liabilities, and own- ers' equity is expressed by the balance sheetequation:

Assets = liabilities + owners' equity

This is a basic accounting equation. Given two of the values, the thirdcan always be found.

The **balance sheet** is usually shown with the assets on the left side and the liabilities and owners' equity on the right side as follows.

Assets		**Liabilities**	
Cash	$100,00	Notes payable	$5,00
Accounts receivable	$300,00	Accounts payable	$20,00
Inventory	$500,00	Long-term debt	$500,00
Fixed assets	$1,000,00 0	Total liabilities	$525,00 0
		Owners' equity	
		Capital	$1,000,00
		Retained earnings	$375,00
Total assets	$1,900,00	Total liabilities and owners' equity	$1,900,00

Capital is the amount of money the owners have invested inthe company.

Retained earnings are increased by the revenues a company makes and decreased by the expenses incurred. The summary of revenues and expenses is shown on the income statement.

Income Statement

Income (profit). The primary purpose of a business is to increase the owners' equity by making a profit. For this reason owners' equity is broken down into a series of accounts, called revenue accounts, which show what increased owners' equity, and expense accounts, which show what decreased owners' equity.

Income = revenue - expenses

Revenue comes from the sale of goods or services. Payment is sometimes imme- diate in the form of cash, but often is made as a promise to pay at a later date, called an account receivable.

Expenses are the costs incurred in the process of making revenue. They are usually categorized into the cost of goods sold and general and administrative expenses.

Cost of goods sold are costs that are incurred to make the product. They include direct labor, direct material, and factory overhead. Factory overhead is all other fac- tory costs except direct labor and direct material.

General and administrative expenses include all other costs in running a business. Examples of these are advertising, insurance, property taxes, and wages and benefits other than direct material, direct labor, and factory overhead costs.

Cash Flow Analysis

When inventory is purchased as raw material, it is recorded as an asset. When it enters production, it is recorded as work-in-process (WIP) inventory, and as it is processed, its value increases by the amount of direct labor applied to it and the overhead attributed to its processing. The material is said to absorb overhead. When the goods are ready for sale, they do not become revenue until they are sold. However, the expenses incurred in producing the goods must be paid for.

This raises another financial issue: Businesses must have the cash to pay their bills. Cash is gen- erated by sales, and the flow of cash into a business must be sufficient to pay bills as they become due. Businesses develop financial statements showing the cash flows into and out of the business. Any shortfall of cash must be provided for, perhaps by borrowing or in someother way. This type of analysis is called cash flow analysis.

Financial Inventory Performance Measures

From a financial point of view, inventory is an asset and represents money that is tied up and cannot be used for other purposes. As we saw previously in this chapter, inventory has a carrying cost—the costs of capital, storage, and risk. Finance wants as little inventory as possible and needs some measure of the level of inventory. Total inventory investment is one measure, but in itself does not relate to sales. Two mea- sures that do relate to sales are the inventory turns ratio and days of supply.

Inventory turns. Ideally, a manufacturer carries no inventory. This is impractical, since inventory is needed to support manufacturing and often to supply customers.

How much inventory is enough? There is no one answer. A convenient measure of how effectively inventories are being used is the

Days of supply **Days of supply** is a measure of the equivalent number of days of inventory on hand, based on usage. The equation to calculate thedays of supply is

$$\text{Days of supply} = \frac{\text{inventory on hand}}{\text{average daily usage}}$$

EXAMPLE PROBLEM

A company has 9000 units on hand and the annual usage is 48,000 units.There are
240 working days in the year. What is the days of supply?

Answer

$$\text{Average daily savings} = \frac{48{,}000}{240} = 200 \text{ units}$$

$$\text{Days of supply} = \frac{\text{inventory on hand}}{\text{average daily usage}} = \frac{9000}{200} = 45 \text{ days}$$

Methods of Evaluating Inventory

There are four methods accounting uses to “cost” inventory: first in first out, last in first out, average cost, and standard cost. Each has implications for the value placed on inven- tory. If there is little change in the price of an item, any of the four ways will produce about the same results. However, in rising or falling prices, there can be a pronounced difference. There is no relationship with the actual physical movement of actual items in any of themethods. Whatever method is used is only to account for usage.

- First in first out (FIFO). This method assumes that the oldest (first) item in stock is sold first. In rising prices, replacement is at a higher price than the assumed cost. This method does not reflect current prices, and replacement will be understated. The reverse is true in a falling price market.

- Last in first out (LIFO). This method assumes the newest (last) item in stock is the first sold. In risingprices, replacement is at the current price. In a falling price market existing inventory is overvalued. However, the company is left with an inventory that may be grossly understated in value.

- Average cost. This method assumes an average of all prices paid for the article. The problem with this method in changing prices (rising or falling) is that the cost used is not related to the actual cost.

- Standard cost. This method uses cost determined before production begins. The cost includes direct material, direct labor, and overhead. Any difference between the standard cost and actual cost is stated as a variance.

Ordering cycle system

Order Quantities

Introduction

The objectives of inventory management are to provide the required level of customer service and to reduce the sum of all costs involved. To achieve these objectives, two basic questions must be answered:

1. How much should be ordered at one time?
2. When should an order be placed?

Management must establish decision rules to answer these questions so inventory management personnel know when to order and how much.Lacking any better knowl- edge, decision rules are often made based on what seems reasonable. Unfortunately, such rules do not always produce thebest results. This chapter will examine methods of answering the first question, and the next chapter will deal with the second question. First, we must decide what we are order- ing and controlling.

Stock-Keeping Unit (SKU)

- Control is exercised through individual items in a particular inventory. These are called **stock-keeping units (SKUs)**. Two white shirts in the same inventory but of dif- ferent sizes or styles would be two different SKUs. The same shirt in two different inventories would be two different SKUs.

Lot-Size Decision Rules

The eleventh edition of the *APICS Dictionary* defines a lot, or batch, as “a quantity pro- duced together and sharing the same production costs and specifications.” Following are some common decision rules for determining what lot size to order at one time.

Lot-for-lot. The **lot-for-lot** rule says to order exactly what is needed— no more— no less. The order quantity changes whenever requirements change. This technique requires time-phased information such as provided by a material requirements plan or a master production schedule. Since items are ordered only when needed, this sys- tem creates no unused lot- size inventory. Because of this, it is the best method for planning A items (see Chapter 9) and is also used in a just-in-time environment.

Fixed-order quantity. **Fixed-order quantity** rules specify the number of units to be ordered each time an order is placed for an individual item or SKU. The quantity is usually arbitrary, such as 200 units at a time. The advantage to this type of rule is that it is easily understood. The disadvantageis that it does not minimize the costs involved.

A variation on the fixed-order quantity system is the **min-max system**. In this system, an order is placed when the quantity available falls below the order point (discussed in the next chapter). The quantity ordered is the difference between the actual quantity available at the time of order and the maximum. For example, if the order point is 100 units, the maximum is 300 units, and the quantity actually available when the order is placed is 75, the order quantity is 225 units. If the quantity actually available is 80 units, an order for 220 units is placed.

One commonly used method of calculating the quantity to order is the economic- order quantity, which is discussed in the next section.

Order n periods supply. Rather than ordering a fixed quantity, inventory man- agement can order enough to satisfy future demand for a given periodof time. The question is how many periods should be covered? The answer is given later in this chapter in the discussion on the period-order quantity system.

The cost of ordering and the cost of carrying inventory both depend on the quantity ordered. Ideally, the ordering decision rules used will minimize the sum of these two costs. The best-known system is the economic-order quantity.

Determination of Economic order quantity and economic lot size

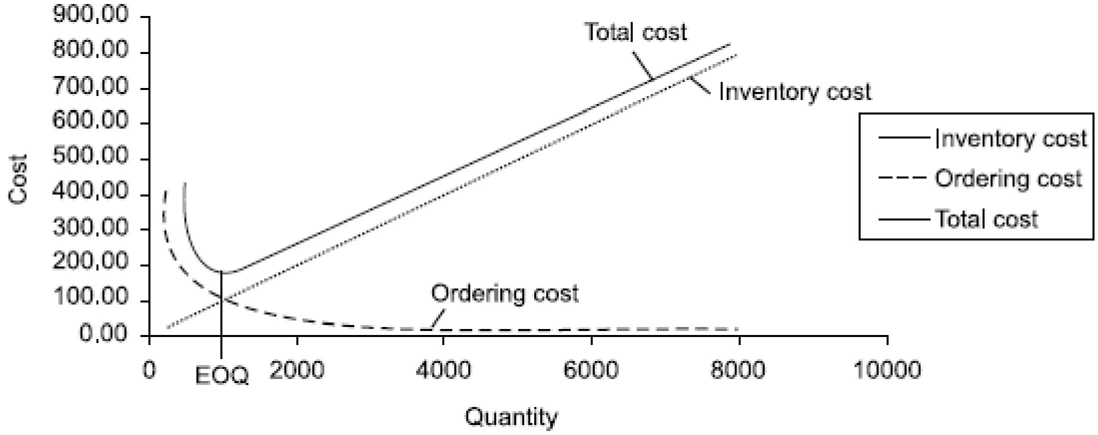
ECONOMIC ORDER QUANTITY (EOQ)

Inventory models deal with idle resources like men, machines, money and materials. These models are concerned with two decisions: how much to order (purchase or produce) and when to order so as to minimize the total cost. For the first decision—how much to order, there are two basic costs are considered namely, inventory carrying costs and the ordering or acquisition costs. As the quantity ordered is increased, the inventory carrying cost increases while the ordering cost decreases. The ‘order quantity means the quantity produced or procured during one production cycle. Economic order quantity is calculated by balancing the two costs.

Economic Order Quantity (EOQ) is that size of order
which minimizes total costs of carrying and cost of ordering.

i.e., Minimum Total Cost occurs when Inventory Carrying Cost = Ordering CostEconomic order quantity can be determined by two methods:

1. Tabulation method.
2. Algebraic method.



Determination of EOQ by Tabulation (Trial & Error) Method

This method involves the following steps:
1. Select the number of possible lot sizes to purchase.
2. Determine average inventory carrying cost for the lot purchased.
3. Determine the total ordering cost for the orders placed.
4. Determine the total cost for each lot size chosen which is the summation of inventory carrying cost and ordering cost.
5. Select the ordering quantity, which minimizes the total cost.
The data calculated in a tabular column can plotted showing the nature of total cost, inventory cost and ordering cost curve against the quantity ordered as in Fig

Definition of the variables

Let Q - Order quantity per order (the unknown / a decision variable) D – Annual Demand C_o - ordering cost per order placed

C_h - Holding cost per unit per year C_p - Unit purchase cost

i - Holding cost expressed as a percentage of unit cost of item.

Note: $C_h = C_p \times i$

e.g. Supposing C_h = Sh.20 and C_p = 100

then it follows that i = 20%The

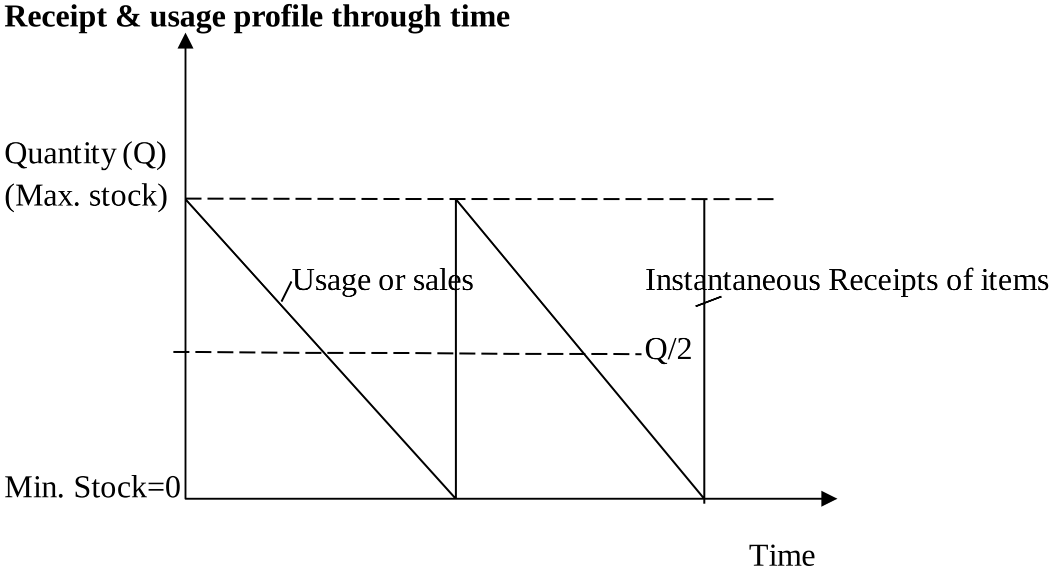
cost formulae are as follows;

i) Ordering Cost = Annual no. of orders x C_o

$$= \frac{D}{Q} \, x \, C_o$$

ii) Holding Cost = Average stock in the year x C_h or Average stock in the year xC_p x I Thus to obtain average stock in the year we need to examine the receipt and usage profiles of stock through time

Receipt & usage profile through time



Notes on graph

1. Instantaneous receipt of items is represented by a 90^0 or vertical line

2. Constant demand (usage rate) is represented by a decreasing linear function.

3. Maximum stock = order quantity Q , since there are no stock-outs i.e minimum stock = 0

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

= (Q +0)/2 = Q/2

Thus Holding cost = $\frac{Q}{2} C_h = \frac{Q}{2} C_{pi}$

At min.TC

$$\frac{Q}{2} C_h = \frac{D}{Q} C_o$$

To obtain the EOQ we make Q the subject as follows;

EOQ = $= \sqrt{\frac{2DCo}{Cpi}}$

Or

EOQ = $= \sqrt{\frac{2DCo}{Ch}}$

2. **Calculus approach**

TC = Purchase Cost + Holding Cost + Ordering Cost (recall there are no shortage costs)In

symbolic form:

TC = $DC_p + \frac{QCh}{2} + \frac{D}{Q} C_o$

The objective now is to find Q which minimizes TC. We apply fist order and second order conditions as follows:

FOC: $\frac{dTC}{dQ} = \frac{C_h}{2} - DC_o Q^{-2} = 0$

$$\frac{Ch}{2} - DCo / Q^2 = 0$$

$C_h/2 = DC_o/Q^2$

Re-arranging: Q^2

$= 2DC_o/C_h$

Hence $Q = \sqrt{\frac{2DCo}{C_h}}$

To confirm the turning point is a minimum, we apply SOC as follows;

SOC:

$d^2TC/dQ^2 = 2DC_oQ^{-3} = 2DC_0/Q^3 > 0$ i.e +ve, since D, Q, C_o are all positive values. Henceturning point is minimum.

Illustration:

Star Logistics Ltd has established that annual quantity for a given item is 4000 units. The cost of placing an order is Sh. 5000 and the price per unit is sh. 2000. Inventory holding cost percentage is 20% of purchase cost.

Required:

a) Formulate the best (optimal) entry policy for this item i.e.

- Quantity to order (EOQ)
- Frequency for ordering and when to order
- Re-order level/point; For ROP take lead-time to be 15 days while one yearhas 300 working days
- Total cost associated with the policy.

b) Suppose it actually turns out that

c) Ordering cost per order = Sh.6000 and

d) Inventory hold cost percentage I = 15% and yet the policy formulated in (a) above is implemented for a year determine the cost of predition error.

Solution:

a) From the illustration we can see that; annual demand, D=4000 units; cost of ordering,Co = sh.5000; carrying cost percentage, i =20% of unit cost; unit purchase cost, Cp=sh 200. Then;

$$EOQ = \sqrt{\frac{DCo}{C_{pi}}}$$

$$= \sqrt{\frac{2 \times 4000 \times 5000}{200 \times 0.2}} \quad = 1000 \text{ units}$$

Frequency of ordering

This is related to the annual number of orders, N which is given as ;

$$N \;=\; \frac{D}{Q} \;=\; \frac{4000}{1000} \;= 4 \text{ orders}$$

Answer

a. Calculate the annual dollar usage for each item.

Part Number	Unit Usage	Unit Cost $	Annual $
1	110	2	2200
2	60	40	24,000
3	10	4	400
4	130	1	1300
5	10	60	6000
6	1	25	250
7	10	2	200
8	150	2	3000
9	20	2	400
10	50	1	500
Tota l	551 0		$38,250

b. **b,** **c**, and **d**.

Part Numb	Annual $ Usage	Cumulati ve	Cumulativ e	Cumulativ e	Class
2	24,000	24,000	62.75	10	A
5	6000	30,000	78.43	20	A
8	3000	33,000	86.27	30	B
1	2200	35,200	92.03	40	B
4	1300	36,500	95.42	50	B
10	500	37,000	96.73	60	C
9	400	37,400	97.78	70	C
3	400	37,800	98.82	80	C
6	250	38,050	99.48	90	C
7	200	38,250	100.00	10	C

The percentage of value and the percentage of items is often shown as a graph, as in Fig 5

Control Based on ABC Classification

Using the ABC approach, there are two general rules to follow:

1. *Have plenty of low-value items.* **C items** represent about 50% of the items but account for only about 5% percent of the total inventory value. Carrying extra stock of C items adds little to the total value of the inventory. C items are really only important if there is a shortage of one of them—when they become extremely important—so a supply should always be on hand. For example, order a year's supply at a time and carry plenty of safety stock. That way there is only oncea year when a stockout is even possible.

2. *Use the money and control effort saved to reduce the inventory of high-value items.*

A items represent about 20% of the items and account for about 80% of the value. They are extremely important and deserve the tightest control and the most frequent review.

Different controls used with different classifications might be the following:

- *A items: high priority.* Tight control including complete accurate records, regular and frequent review by management, frequent reviewof demand forecasts, and close follow-up and expediting to reduce lead time.
- *B items: medium priority.* Normal controls with good records, regular attention, and normal processing.
- *C items: lowest priority.* Simplest possible controls—make sure thereare plenty.

Simple or no records; perhaps use a two-bin system or periodic review system.

Order large quantities and carry safety stock.

Recorder procedure (JIT)

Standardized Components and Work Methods

The standardization of components, called part commonality or modularity, increases repeatability. For example, a firm producing 10 products from 1000 different components could redesign its products so that they consist of only 100 different components with larger daily requirements. Because the requirements per component increase, so does repeatability; that is, each worker performs a standardized task or work method more ofteneach day. Productivity tends to increase because, with increased repetition, workers learn to do the task more efficiently Standardization of components and work methods aids in achieving the high-productivity, low-inventory objectives of JIT systems.

Close Supplier Ties

Because JIT systems operate with very low levels of inventory, close relationships with suppliers are necessary. Stock shipments must be frequent, have short lead times, arrive on schedule, and be of high quality. A contract might require a supplier to deliver goods to a factory as often as several times per day. Purchasing managers focus on three areas: reducing the number of suppliers, using local suppliers, and improving supplier relations.

Typically, one of the first actions undertaken when a JIT system is implemented is to pare the number of suppliers. Xerox, for example, reduced the number of its suppliers from5000 to just 300. This approach puts a lot of pressure on these suppliers to deliver high- quality components on time. To compensate, JIT users extend their contracts with these suppliers and give them firm advance-order information. In addition, they include their suppliers in the early phases of product design to avoid problems after production has begun. They also work with their suppliers' vendors, trying to achieve JIT inventory flows throughout the entire supply chain.

Manufacturers using JIT systems generally utilize local suppliers. For instance, when GM located its Saturn complex in Tennessee, many suppliers clustered nearby. Harley- Davidson reduced the number of its suppliers and gave preference to those close to its plants--for example, three-fourths of the suppliers for the Milwaukee engine plant are located within a 175-mile radius. Geographic proximity means that the company can reduce the need for safety stocks. Companies that have no suppliers close by must rely on afinely tuned supplier delivery system. For example, New United Motor Manufacturing, Incorporated (NUMMI), the joint venture between GM and Toyota in California, has suppliers in Indiana, Ohio, and Michigan. Through a carefully coordinated system involving trains and piggyback truck trailers, suppliers deliver enough parts for exactly oneday's production each day.

Users of JIT systems also find that a cooperative orientation with suppliers is essential. The JIT philosophy is to look for ways to improve efficiency and reduce inventories throughout the supply chain. Close cooperation between companies and their suppliers can be a win-win situation for everyone. Better communication of component requirements, for example, enables more efficient inventory planning and delivery scheduling by suppliers, thereby improving supplier profit margins. Customers can then negotiate lower component prices. Suppliers also should be included in the design of new products so that inefficient component designs can be avoided before production begins. Close supplier relations can't be established and maintained if companies view their suppliers as adversaries whenever contracts are negotiated. Rather, they should consider suppliers to be partners in a venture wherein both parties have an interest in maintaining a long-term, profitable relationship.

Flexible Work Force

Workers in flexible work forces can be trained to perform more than one job. When the skill levels required to perform most tasks are low--at a McDonald's restaurant, for instance--a high degree of flexibility in the work force can be achieved with little training. In situations requiring higher skill levels, such as at the Texas Instruments antenna department, shifting workers to other jobs may require extensive, costly training.
Flexibility can be very beneficial: Workers can be shifted among workstations to help relieve bottlenecks as they arise without resorting to inventory buffers--an important aspect of the uniform flow of JIT systems. Or they can step in and do the job for those on vacation or out sick. Although assigning workers to tasks they don't usually perform may reduce efficiency, some rotation relieves boredom and refreshes workers.

Line Flow Strategy

A line flow strategy can reduce the frequency of setups. If volumes of specific products are large enough, groups of machines and workers can be organized into a product layout to eliminate setups entirely. If volume is insufficient to keep a line of similar products busy, group technology can be used to design small production lines that manufacture, in volume, families of components with common attributes. Changeovers from a component in one product family to the next component in the same family are minimal.

Another tactic used to reduce or eliminate setups is the one-worker, multiple machines (OWMM) approach, which essentially is a one-person line. One worker operates several machines, with each machine advancing the process a step at a time. Because the same product is made repeatedly, setups are eliminated. For example, in a McDonald's restaurant the person preparing fish sandwiches uses the OWMM approach. When the signal is given to produce more fish sandwiches, the employee puts the fish patties into the fish fryer and sets the timer. Then while the fish are frying, he puts the buns into the steamer. When the buns are finished, he puts them on a tray and dresses them with condiments. When the fish patties are ready, he inserts them into the buns. He then places the completed sandwiches on the shelf for the final assembler to package for the customer. The cycle is repeated throughout the day.

Automated Production

Automation plays a big role in JIT systems and is a key to low-cost production. Sakichi Toyoda, the founder of Toyota, once said, "Whenever there is money, invest it into machinery. " Money freed up because of JIT inventory reductions can be invested in automation to reduce costs. The benefits, of course, are greater profits, greater market share (because prices can be cut), or both. Automation should be planned carefully, however.

Many managers believe that if some automation is good, more is better. That isn't always the case. When GM initiated Buick City, for example, it installed 250 robots, some with vision systems for mounting windshields. Unfortunately, the robots skipped black cars because they couldn't "see" them. New software eventually solved the problem; however, GM management found that humans could do some jobs better than robots and replaced 30 robots with humans. That lesson carried over to GM's Opel plant in Eisenach, Germany, where radiators and windshields are now installed by hand.

Preventive Maintenance

Because JIT emphasizes finely tuned mows of materials and little buffer inventory between workstations, unplanned machine downtime can be disruptive. Preventive maintenance can reduce the frequency and duration of machine downtime. After performing routine maintenance activities, the technician can test other parts that might need to be replaced.

Replacement during regularly scheduled maintenance periods is easier and quicker than dealing with machine failures during production. Maintenance is done on a schedule that balances the cost of the preventive maintenance program against the risks and costs of machine failure.

Another tactic is to make workers responsible for routinely maintaining their own equipment and develop employee pride in keeping their machines in top condition. This tactic, however, typically is limited to general housekeeping chores, minor lubrication, and adjustments. Maintenance of high-tech machines needs trained specialists. Doing even simple maintenance tasks goes a long way toward improving machine performance, though.

Introduction to computer integrated production planning systems elements ofJust In Time Systems(JITS)

To gain and maintain a competitive advantage, firms are using the just-in-time (JIT) philosophy, which is to eliminate waste by cutting unnecessary inventory and removing delays in operations. The goals are to produce goods and services as needed and to continuously improve the value-added benefits of operations. A JIT system is the organization of resources, information flows, and decision rules that can enable an organization to realize the benefits of the JIT philosophy. Often a crisis (such as being faced with going out of business or closing a plant) galvanizes management and labor to work together to change traditional operating practices. Converting from traditional manufacturing to a just-in-time system brings up not only inventory control issues, but also process management and scheduling issues. In this chapter we identify the characteristics of JIT systems, discuss how they can be used for continuous improvement of operations, and indicate how manufacturing and service operations utilize such systems. We also address the strategic implications of JIT systems and some of the implementation issues that companies face. Finally, we discuss the choice of an appropriate production and inventory management system for a particular environment.

CHARACTERISTICS OF JUST-IN-TIME SYSTEMS

Just-in-time systems focus on reducing inefficiency and unproductive time in the production process to improve continuously the process and the quality of the product or service. Employee involvement and inventory reduction are essential to JIT operations. Just-in-time systems are known by many different names, including zero inventory, synchronous manufacturing, lean production, stockless production (Hewlett-Packard), material as needed (Harley-Davidson), and continuous flow manufacturing (IBM). In thissection we discuss the following characteristics of JIT systems: pull method of material mow, consistently high quality, small lot sizes, uniform workstation loads, standardized components and work methods, close supplier ties, flexible work force, line flow strategy, automated production, and preventive maintenance.

Pull Method of Materials Flow

Just-in-time systems utilize the pull method of materials flow. However, another popular method is the push method. To differentiate between these two systems, let's first consider the production system for a Quarter Pounder at a McDonald's restaurant. There are two workstations. The burger maker is the person responsible for producing this burger:Burger patties must be fried; buns must be toasted and then dressed with ketchup, pickles, mayonnaise lettuce, and cheese; and the patties must be inserted into buns and put on a tray. The final assembler takes the tray, wraps the burgers in paper, and restocks the inventory. Inventories must be kept low because any burgers left unsold after seven minutes must be destroyed.

The flow of materials is from the burger maker to the final assembler to the customer. One way to manage this flow is by using the push method, in which the production of the item begins in advance of customer needs. With this method, management schedules the receipt of all raw materials (e.g., meat, buns, and condiments) and authorizes the start of production, all in advance of Quarter Pounder needs. The burger maker starts production of 24 burgers (the capacity of the griddle) and, when they are completed, pushes them along to the final assembler's station, where they might have to wait until she is ready for them. The packaged burgers then wait on a warming tray until a customer purchases one.

JUST-IN-TIME

The other way to manage the flow among the burger maker, the final assembler, and the customer is to use the pull method, in which customer demand activates production of the item. With the pull method, as customers purchase burgers, the final assembler checks the inventory level of burgers and, when they are almost depleted, orders six more. The burger maker produces the six burgers and gives the tray to the final assembler, who completes the assembly and places the burgers in the inventory for sale. The pull method is better for the production of burgers: The two workers can coordinate the two workstations to keep inventory low, important because of the seven-minute time limit. The production of burgers is a highly repetitive process, setup times and process times are low, and the flow of materials is well defined. There is no need to produce to anticipated needs more than a few minutes ahead.

Firms that tend to have highly repetitive manufacturing processes and well-defined material flows use just-in-time systems because the pull method allows closer control of inventory and production at the workstations. Other firms, such as those producing a large variety of products in low volumes with low repeatability in the production process, tend to use a push method such as MRP. In this case a customer order is promised for delivery on some future date. Production is started at the first workstation and pushed ahead to the next one. Inventory can accumulate at each workstation because workstations are responsible for producing many other orders and may be busy at any particular time.

Consistently High Quality

Just-in-time systems seek to eliminate scrap and rework in order to achieve a uniform flow of materials. Efficient JIT operations require conformance to product or service specifications and implementation of the behavioral and statistical methods of total quality management (TQM). JIT systems control quality at the source, with workers acting as their own quality inspectors. For example, a soldering operation at the Texas Instruments antenna department had a defect rate that varied from zero to 50 percent on a daily basis, averaging about 20 percent. To compensate, production planners increased the lot sizes, which only increased inventory levels and did nothing to reduce the number of defective items. Engineers discovered through experimentation that gas temperature was a critical variable in producing defect-free items. They devised statistical control charts for the operators to use to monitor gas temperature and adjust it themselves. Process yields immediately improved and stabilized at 95 percent, eventually enabling management to implement a JIT system.

Management must realize the enormous responsibility this method places on the workers and must prepare them properly, as one GM division quickly learned. When Buick City began using JIT in 1985, management authorized its workers to stop the production line by pulling a cord if quality problems arose at their stations-a practice the Japanese call *andon*. GM also eliminated production-line inspectors and cut the number of supervisors by half. Stopping the line, however, is a costly action that brings a problem to everyone's attention. The workers weren't prepared for that responsibility; productivity and quality took a nose-dive. The paint on Le Sabres wasn't shiny enough. The seams weren't straight. The top of the dashboard had an unintended wave. Management, labor, and engineering formed a team to correct the problems. Work methods were changed, and the *andon* system was modified to include a yellow warning cord so that workers could call for help without stopping the line.

Small Lot Sizes

Rather than building up a cushion of inventory, users of JIT systems maintain inventory with lot sizes that are as small as possible. Small lot sizes have three benefits. First, small lot sizes reduce cycle inventory, the inventory in excess of the safety stock carried betweenorders (see the Inventory Management chapter). The average cycle inventory equals one- half the lot size: As the lot size gets smaller, so does cycle inventory. Reducing cycle inventory reduces the time and space involved in manufacturing and holding inventory

Second, small lot sizes help cut lead times. A decline in lead-time in turn cuts pipeline (WIP) inventory because the total processing time at each workstation is greater for large lots than for small lots. Also, a large lot often has to wait longer to be processed at the next workstation while that workstation finishes working on another large lot. In addition, if any defective items are discovered, large lots cause longer delays because the entire lot must be inspected to find all the items that need rework.

Finally, small lots help achieve a uniform operating system workload. Large lots consume large chunks of processing time on workstations and therefore complicate scheduling. Small lots can be juggled more effectively, enabling schedulers to utilize capacities more efficiently. In addition, small lots allow workstations to accommodate mixed-model production (more than one item) by reducing waiting line times for production. We return to this point when we discuss uniform workstation loads.

Although small lot sizes are beneficial to operations, they have the disadvantage of increased setup frequency. In operations where the setup times are normally low, as in the McDonald's example, small lots are feasible. However, in fabrication operations with sizable setup times, increasing the frequency of setups may result in wasting employee andequipment time. These operations must reduce setup times to realize the benefits of small- lot production.

Uniform Workstation Loads

The JIT system works best if the daily load on individual workstations is relatively uniform. Uniform loads can be achieved by assembling the same type and number of units each day, thus creating a uniform daily demand at all workstations. Capacity planning, which recognizes capacity constraints at critical workstations, and line balancing are used to develop the monthly master production schedule. For example, at Toyota the aggregate production plan may call for 4500 minivans per week for the next month. That requires twofull shifts, five days per week, producing 900 minivans each day, or 450 per shift. Three models of minivans are produced: Camry (C), Avalon (A), and Sienna (S). Suppose that Toyota needs 200 Camrys, 150 Avalons, and 100 Siennas per shift to satisfy market demand. To produce 450 units in one shift of 480 minutes, the line must roll out a minivan every 480/450 = 1.067 minutes.

Three ways of devising a master production schedule for the minivans are of interest here. First, with big-lot production, all daily requirements of a model are produced in one batch before another model is started. The sequence of 200 C's, 150 As, and 100 S's would be repeated once per shift. Not only would these big lots increase the average cycle inventory level, but they also would cause lumpy requirements on all the workstations feeding the assembly line.

The second option uses mixed-model assembly, producing a mix of models in smaller lots. Note that the production requirements are in the ratio of 4 C's to 3 A's to 2 S's, found by dividing the model's production requirements by the greatest common divisor, or 50. Thus the Toyota planner could develop a production cycle consisting of 9 units: 4 C's, 3 As, and 2 S's. The cycle would repeat in 9(1.067)= 9.60 minutes, for a total of 50 times per shift (480 min/9.60 min = 50).

A sequence of C-S-C-A-C-A-C-S-A, repeated 50 times per shift, would achieve the same total output as the other options. This third option is feasible only if the setup times are very short. The sequence generates a steady rate of component requirements for the various models and allows the use of small lot sizes at the feeder workstations. Consequently, the capacity requirements at those stations are greatly smoothed. These requirements can be compared to actual capacities during the planning phase, and modifications to the production cycle, production requirements, or capacities can be made as necessary.

Fundamentals of MRP II.

Enterprise Resource Planning- Introduction

ERP is an acronym that stands for <u>E</u>nterprise <u>R</u>esource <u>P</u>lanning. ERP software saw phenomenal interest from the corporate sector during the period 1995-2000. Substantial investments (often running into millions of dollars) were made in hardware, software, consulting and training to support ERP implementations. The ERP market is estimated to be in excess of USD 80 Billion in the year 2000 [1]. Significant benefits are associated with successful implementation of ERP in the Fortune 500 companies - in the form of faster inventory turnover, higher capacity utilization, faster time to market and overall profitability. Many analysts feel that today’s global business environment - products and services customized to suit the individual needs of millions of customers, delivered over multiple timelines in a 24X7 basis - would have been impossible without such enterprise software. Undoubtedly ERP represents one of the most complex and demanding application software in the corporate environment.

What is ERP?

ERP is a <u>package software solution</u> that addresses the <u>enterprise needs</u> of an organization by <u>tightly integrating</u> the various functions of an organization using a <u>process view</u> of the organization.

A. ERP software is ready-made generic software; it is not custom-made for a specific firm. ERP software understands the needs of any organization within a specific industry segment. Many of the processes implemented in an ERP software are core processes such as order processing, order fulfillment, shipping, invoicing, production planning, BOM (Bill of Material), purchase order, general ledger, etc., that are common to all industry segments. That is the reason why the package software solution works so well. The firm-specific needs are met through a process of customization.

B. ERP does not merely address the needs of a single function such as finance, marketing, production or HR; rather it addresses the entire needs of an enterprise that cuts across these functions to meaningfully execute any of the core processes.

C. ERP integrates the functional modules tightly. It is not merely the import and export of data across the functional modules. The integration ensures that the logic of a process that cuts across the function is captured genuinely. This in turn implies that data once entered in any of the functional modules (whichever of the module owns the data) is made available to every other module that needs this data. This leads to significant improvements by way of improved consistency and integrity of data.

D. ERP uses the process view of the organization in the place of function view, which dominated the enterprise software before the advent of ERP. The process view provides a much better insight into the organizational systems and procedures and also breaks the "kingdoms" that work at cross-purposes in many organizations.

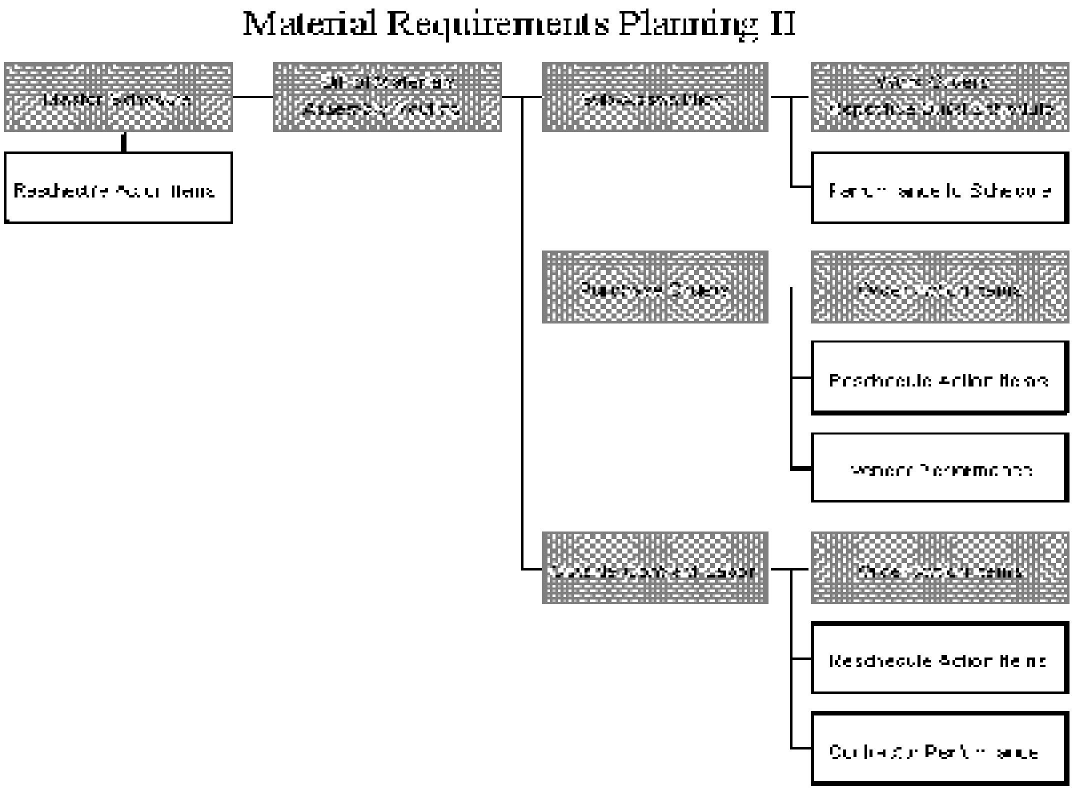
To implement such a demanding software one needs high performance computing, high availability systems, large, high-speed, high-availability on-line storage and high-speed, high-reliable networks, all at affordable cost.

Why ERP?

In spite of heavy investments involved in ERP implementation, many organizations around the world have gone in for ERP solutions. A properly implemented ERP solution would pay for the heavy investments handsomely and often reasonably fast. Since ERP solutions address the entire organizational needs, and not selected islands of the organization, ERP introduction brings a new culture, cohesion and vigor to the organization. After ERP introduction the line managers would no longer have to chase information, check compliance to rules or conformance to budget. What is striking is that a well-implemented ERP can guarantee these benefits even if the organization is a multi-plant, multi- location global operation spanning the continents. In a sense ERP systems can be compared to the “fly-by-wire” operation of an aircraft. ERP systems similarly would relieve operating managers of routine decisions and leave them with lots of time to think, plan and execute vital long-term decisions of an organization. Just as “fly-by-wire” operation brings in amazing fuel efficiency to the aircraft operation by continuous monitoring of the airplane operation, ERP systems lead to significant cost savings by continuously monitoring the organizational health. The seemingly high initial investments become insignificant in the face of hefty long-term returns

Fundamentals of ERP.

ERP



To assist planners in tracking some of the problems associated with inventory control, some kind of 'feedback loop' is needed in the M.R.P. process, not only to automatically re-schedule certain items (when possible), and avoid excessive manual effort in controlling the process, but to detect and report performance that is 'out of spec' (such as a vendor performance report to track on-time delivery performance). This 'feedback loop' is the defining factor for an 'M.R.P. II' system. Though many systems **CLAIM** to be an 'M.R.P. II' system, few actually fit the mould exactly. Still, with automatic rescheduling capabilities for work orders and/or repetitive build schedules, and 'reschedule action' reports for purchase orders and outside contracting, the amount of actual analysis is reduced significantly. Other information, such as vender performance reports and process utilization reports, also help to measure the

'performance to plan' capability of the manufacturing plant.

Even when the production plan is running at optimum performance, companies still often have serious problems with the manufacturing process. ‘Hidden Cost’ issues associated with manufacturing increase the total cost of manufacturing, but are extremely hard to track. Some of these ‘Hidden Costs’ can be caused by excessive

P.O. rescheduling or excessive ‘crash buy’ programs, excess and/or obsolete inventory, or planning problems that cause incorrectly stocked finished goods (too much of one, not enough of the other) that result in shortages. Another ‘hidden cost’ issue might be frequent line stops related to a ‘limiting process’ (such as a wave solder machine or component inserter), as well as material shortages and excessive
‘kitting’ of common components. In addition, potential revenue losses from excessively long customer order lead times, or poor on-time customer delivery performance, are real problems, but very difficult to track and measure. As such, none of these problems are tracked nor reported by any ‘standard M.R.P.’ or ‘M.R.P. II’ system. To help solve these problems, and improve the company’s competativeness and profitability, beyond existing capabilities, the M.R.P. system must go beyond the standard definition of ‘M.R.P. II’.

Manufacturing Resource Planning (**MRP II**) is defined by APICS (American Production and Inventory Control Society, Estd. 1957) as a method for the effective planning of all resources of a manufacturing company. Ideally, it addresses operational planning in units, financial planning in dollars, and has a simulation capability to answer "what-if" questions and extension of closed-loop MRP.

This is not exclusively a software function, but a marriage of people skills, dedication todata base accuracy, and computer resources. It is a total company management concept for using human resources more productively.

MRP II is not

Many items on this list can be part of an MRP II, but are not solely what it is.

- a computer system
- manufacturing control system
- inventory reduction plan
- Sales & Purchase System
- Material Management

Purpose

MRP II integrates many areas of the manufacturing enterprise into a single entity for planning and control purposes, from board level to operative and from five-year plan to individual shop-floor operation. It builds on closed-loop Material Requirements Planning (MRP) by adopting the feedback principle but extending it to additional areas of the enterprise, primarily manufacturing-related.

Key functions and Features

MRP II is not a proprietary software system and can thus take many forms. It is almost impossible to visualise an MRP II system that does not use a computer, but an MRP II system can be based on either purchased / licensed or in-house software.

Almost every MRP II system is modular in construction. Characteristic basic modules inan MRP II system are:

- Master Production Scheduling (MPS)
- Item Master Data (Technical Data)
- Bill of Materials (BOM) (Technical Data)
- Production Resources Data (Manufacturing Technical Data)
- Inventories & Orders (Inventory Control)
- Purchasing Management
- Material Requirements Planning (MRP)
- Shop Floor Control (SFC)
- Capacity planning or Capacity Requirements Planning (CRP)
- Standard Costing (Cost Control)
- Cost Reporting / Management (Cost Control)
- Distribution Resource Planning (DRP)to

gether with ancillary systems such as:

- Business Planning
- Lot Traceability
- Contract Management
- Tool Management
- Engineering Change Control

- Configuration Management
- Shop Floor Data Collection
- Sales Analysis and Forecasting
- Finite Capacity Scheduling (FCS)

and related systems such as:

- General Ledger
- Accounts Payable (Purchase Ledger)
- Accounts Receivable (Sales Ledger)
- Sales Order Management
- Distribution Requirements Planning (DRP)
- [Automated] Warehouse Management
- Project Management
- Technical Records
- Estimating
- Computer-aided design/Computer-aided manufacturing (CAD/CAM)
- CAPP

The MRP II system integrates these modules together so that they use common data and freely exchange information, in a model of how a manufacturing enterprise should and can operate. The MRP II approach is therefore very different from the "point solution" approach, where individual systems are deployed to help a company plan, control or manage a specific activity. MRP II is by definition fully integrated or at least fully interfaced.