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Production & Operation Management

Institute of **Open** and **Distance Education**

**Faculty of Management**

# Production & Operation Management

**2MBA6**

**DR. C.V. RAMAN UNIVERSITY**

Chhattisgarh, Bilaspur

A STATUTORY UNIVERSITY UNDER SECTION 2(F) OF THE UGC ACT

# 2MBA6

# Production & operation Management

2MBA6
Production & operation Management

Credit-2

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# TABLE OF CONTENTS

# BLOCK I

# 1 INTRODUCTION TO PRODUCTION MANAGEMENT

*The Chapter Covers :*



***Learning Objectives:***

After going through this chapter, you should be able to

- Explain operation management and production planning
- Describe production management
- Clarify Work Study
- Discuss manufacturing operations and service operations
- Explain scope, objectives of production and operation management

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# 1.1 INTRODUCTION

Today the situation is that a person will not be treated as educated if he knows nothing about Commerce, Economics, Science and Technology. Production management is not represented by any one of these fields but is delicate blend of them all. The development of production management has been extremely rapid. Through production system we make available goods and services in a vast quantity. A century ago, the man of education was judged by his art, literature and language.

Production/operations management is the process, which combines and transforms various resources used in the production/operations subsystem of the organization into value added product/services in a controlled manner as per the policies of the organization. Therefore, it is that part of an organization, which is concerned with the transformation of a range of inputs into the required (products/services) having the requisite quality level. The set of interrelated management activities, which are involved in manufacturing certain products, is called as production management. If the same concept is extended to services management, then the corresponding set of management activities is called as **Operations Management.**

Production management techniques are used in both manufacturing and service industries. Production management responsibilities include the traditional "five M's": men and women, machines, methods, materials, and money. Production management, alternatively referred to as manufacturing management, is required for transforming raw materials and partly, fabricated materials into finished products. Production management does not imply management of productive process alone, but it covers all there activities which go into the making of production. To make production a concrete reality, one, must pay attention to the factors of production like land, labour, capital and organization, or to speak in the language of business, materials, men, money, machines and methods. Production management thus calls for the work of planning and control pertaining to each of these factors of production.

Production management does not involve a mechanical assemblage of relevant factors. In contrast to mere transformation of raw materials into finished products, it aims at transmuting and permuting resources of higher productivity so that the greatest outputs are obtained from the least inputs. With its end in views, production management embraces the productive process too and involves planning, directing and controlling operations till their successful completion. Quality, quantity, cost and time of production has an important bearing on productivity of the manufacturing enterprise.

Accordingly, it is the task of production management to see that effective utilization of resources is made, time is shortened, wastes and scrapings are avoided, and harmonious working is made to prevail in the plant.

Production management is a process of planning, organizing, directing and controlling the activities of the production function. It combines and transforms various resources used in the production subsystem of the organization into value added product in a controlled manner as per the policies of the organization.

E.S. Buffa defines production management as, "Production management deals with decision making related to production processes so that the resulting goods or services are produced according to specifications, in the amount and by the schedule demanded and out of minimum cost."

## 1.2 OPERATIONS MANAGEMENT

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### A Framework for Managing Operations

Managing operations can be enclosed in a frame of general management function. Operation managers are concerned with planning, organizing, and controlling the activities which affect human behavior through models.

#### PLANNING

Activities that establishes a course of action and guide future decision-making is planning. The operations manager defines the objectives for the operations subsystem of the organization, and the policies, and procedures for achieving the objectives. This stage includes clarifying the role and focus of operations in the organization's overall strategy. It also involves product planning, facility designing and using the conversion process.

#### ORGANIZING

Activities that establishes a structure of tasks and authority. Operation managers establish a structure of roles and the flow of information within the operations subsystem. They determine the activities required to achieve the goals and assign authority and responsibility for carrying them out.

#### CONTROLLING

***Activities that assure the actual performance in accordance with planned performance.*** To ensure that the plans for the operations subsystems are accomplished, the operations manager must exercise control by measuring actual outputs and comparing them to planned operations management. Controlling costs, quality, and schedules are the important functions here.

#### BEHAVIOUR

Operation managers are concerned with how their efforts to plan, organize, and control affect human behavior. They also want to know how the behavior of subordinates can affect management's planning, organizing, and controlling actions. Their interest lies in decision-making behavior.

#### MODELS

As operation managers plan, organize, and control the conversion process, they encounter many problems and must make many decisions. They can simplify their difficulties using models like aggregate planning models for examining how best to use existing capacity in short-term, break even analysis to identify break even volumes, linear programming and computer simulation for capacity utilization, decision tree analysis for long-term capacity problem of facility expansion, simple median model for determining best locations of facilities etc.

## 1.3 HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT

For over two centuries operations and production management has been recognized as an important factor in a country's economic growth. The traditional view of manufacturing management began in eighteenth century when Adam Smith recognized the economic benefits of specialization of labor. He recommended breaking of

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jobs down into subtasks and recognizes workers to specialized tasks in which they would become highly skilled and efficient. In the early twentieth century, F.W. Taylor implemented Smith's theories and developed scientific management. From then till 1930, many techniques were developed prevailing the traditional view. Brief information about the contributions to manufacturing management is shown in the date line 1.1.

**Date line 1.1 Historical summary of operations management**

| *Date* | *Contribution* | *Contributor* |
|---|---|---|
| 1776 | Specialization of labor in manufacturing | Adam Smith |
| 1799 | Interchangeable parts, cost accounting | Eli Whitney and others |
| 1832 | Division of labor by skill; assignment of jobs by skill; basics of time study | Charles Babbage |
| 1900 | Scientific management time study and work study developed; dividing planning and doing of work | Frederick W. Taylor |
| 1900 | Motion of study of jobs | Frank B. Gilbreth |
| 1901 | Scheduling techniques for employees, machines jobs in manufacturing | Henry L. Gantt |
| 1915 | Economic lot sizes for inventory control | F.W. Harris |
| 1927 | Human relations; the Hawthorne studies | Elton Mayo |
| 1931 | Statistical inference applied to product quality: quality control charts | W.A. Shewart |
| 1935 | Statistical sampling applied to quality control: inspection sampling plans | H.F. Dodge & H.G. Roming |
| 1940 | Operations research applications in World War II | P.M. Blacker and others. |
| 1946 | Digital computer | John Manchlly and J.P. Eckert |
| 1947 | Linear programming | G.B. Dantzig, Williams & others |
| 1950 | Mathematical programming, on-linear and stochastic processes & others | A. Charnes, W.W. Cooper |
| 1951 | Commercial digital computer: large-scale computations available. | Sperry Univac |
| 1960 | Organizational behavior: continued study of people at work | L. Cummings, L. Porter |
| 1970 | Integrating operations into overall strategy and policy, Computer applications to manufacturing, Scheduling and control, Material requirement planning (MRP) | W. Skinner J. Orlicky G. Wright |
| 1980 | Quality and productivity applications from Japan: robotics, CAD-CAM | W.E. Deming and J. Juran. |

**Production** management becomes the acceptable term from 1930s to 1950s. As F.W. Taylor's works become more widely known, managers developed techniques that focused on economic efficiency in manufacturing. Workers were studied in great detail to eliminate wasteful efforts and achieve greater efficiency. At the same time, psychologists, socialists and other social scientists began to study people and human behavior in the working environment.

In addition, economists, mathematicians, and computer socialists contributed newer, more sophisticated analytical approaches.

With the 1970s emerge two distinct changes in our views. The most obvious of these, reflected in the new name operations management was a shift in the service and manufacturing sectors of the economy. As service sector became more prominent, the change from 'production' to 'operations' emphasized the broadening of our field to service organizations. The second, more suitable change was the beginning of an emphasis on synthesis, rather than just analysis, in management practices.

## 1.4 OBJECTIVES OF PRODUCTION MANAGEMENT:

The objective of the production management is 'to produce goods services of right quality and quantity at the right time and right manufacturing cost'.

1) **Right quality:** The quality of product is established based upon the customers needs. The right quality is not necessarily best quality. It is determined by the cost of the product and the technical characteristics as suited to the specific requirements.

2) **Right quantity:** The manufacturing organization should produce the products in right number. If they are produced in excess of demand the capital will block up in the form of inventory and if the quantity is produced in short of demand, leads to shortage of products.

3) **Right time:** Timeliness of delivery is one of the important parameter to judge the effectiveness of production department. So, the production department has to make the optimal utilization of input resources to achieve its objective.

4) **Right manufacturing cost:** Manufacturing costs are established before the product is actually manufactured. Hence, all attempts should be made to produce the products at pre-established cost, so as to reduce the variation between actual and the standard (pre-established) cost.

## 1.5 SCOPE OF PRODUCTION AND OPERATIONS MANAGEMENT

Production management concerns with the conversion of inputs into outputs, using physical resources, so as to provide the desired utilities to the customer. It distinguishes itself from other functions such as personnel, marketing, finance, etc., by its primary concern for 'conversion by using physical resources.' Following are the activities which are listed under production and operations management functions:

i) Location of facilities
ii) Plant layouts and material handling
iii) Product design
iv) Process design
v) Production and planning control
vi) Quality control
vii) Materials management
viii) Maintenance management.

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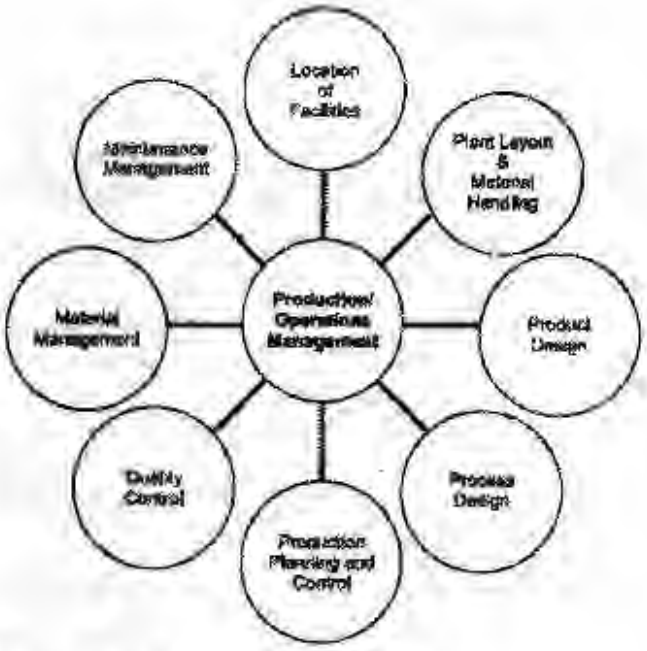


*Scope of production and operations management*

## 1. LOCATION OF FACILITIES:

Location of facilities for operations is a long-term capacity decision which involves a long term commitment about the geographically static factors that affect a business organization. It is an important strategic level decision-making for an organization. It deals with the questions such as 'where our main operations should be based?'

The selection of location is a key-decision as large investment is made in building plant and machinery. An improper location of plant may lead to waste of all the investments made in plant and machinery equipments. Hence, location of plant should be based on the company's expansion plan and policy, diversification plan for the products, changing sources of raw materials and many other factors. The purpose of the location study is to find the optimal location that will results in the greatest advantage to the organization.

## 2. PLANT LAYOUT AND MATERIAL HANDLING:

Plant layout refers to the physical arrangement of facilities. It is the configuration of departments, work centers and equipment in the conversion process. The overall objective of the plant layout is to design a physical arrangement that meets the required output quality and quantity most economically.

According to James Moore, "Plant layout is a plan of an optimum arrangement of facilities including personnel, operating equipment, storage space, material handling equipments and all other supporting services along with the design of best structure to contain all these facilities".

'Material Handling' refers to the 'moving of materials from the store room to the machine and from one machine to the next during the process of manufacture'. It is also defined as the 'art and science of moving, packing and storing of products in any form'. It is a specialized activity for a modern manufacturing concern, with 50 to 75% of the cost of production. This cost can be reduced by proper section, operation and maintenance of material handling devices. Material handling devices increases the output, improves quality, speeds up the deliveries and decreases the cost

of production. Hence, material handling is a prime consideration in the designing new plant and several existing plants.

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### 3. PRODUCT DESIGN:

Product design deals with conversion of ideas into reality. Every business organization has to design, develop and introduce new products as a survival and growth strategy. Developing the new products and launching them in the market is the biggest challenge faced by the organizations.

The entire process of need identification to physical manufactures of product involves three functions: marketing, product development, and manufacturing. Product development translates the needs of customers given by marketing into technical specificanons and designing the various features into the product to these specifications. Manufacturing has the responsibility of selecting the processes by which the product can be manufactured. Product design and development provides link between marketing, customer needs and expectations and the activities required to manufacture the product.

### 4. PROCESS DESIGN:

Process design is a macroscopic decision-making of an overall process route for converting the raw material into finished goods. These decisions encompass the selection of a process, choice of technology, process flow analysis and layout of the facilities. Hence, the important decisions in process design are to analyze the workflow for converting raw material into finished product and to select the workstation for each included in the workflow.

### 5. PRODUCTION PLANNING AND CONTROL:

Production planning and control can be defined as the process of planning the production in advance, setting the exact route of each item, fixing the starting and finishing dates for each item, to give production orders to shops and to follow up the progress of products according to orders.

The principle of production planning and control lies in the statement 'First Plan Your Work and then Work on Your Plan'.

Planning may be defined as "Any information which either specifies or guides the taking of future actions by its members geared towards overcoming existing or anticipated problems". Billy E. Goetz has rightly remarked planning as "fundamentally choosing", and "a planning problem arises when an alternative course of action is discovered". So, in simplest way, we may define production planning as planning of production. But production planning requires a careful and elaborate study of coordinating and related activities which are necessarily performed by different departments. Messrs. Bethol, Smith and others in their book 'Industrial Organization and Management' have defined the production planning as "It is a series of related and co-ordinate activities performed by not one but a number of different departmental groups, each activity being designed to systematize in advance the manufacturing efforts in its area".

According to Alford and Beatty, "Production planning and control comprise the planning, routing scheduling, dispatching and follow up function in the productive process, as organized that the movements of material, performance of machines and operations of labor, however subdivided, are direct and coordinated as to quantity, quality time and place. It is adopting as business principle the old saying plan your work and work your plan."

**According to Charles Akoepke,** "Production planning and control may be defined as the coordination of a series of functions according to a plan which will, economically utilize the plant facilities and regulate the orderly movement of goods through their entire manufacturing cycle, from the procurement of all materials to the shipping of finished goods at a predetermined rate."

**According to Alford and Beatty,** "Production planning and control comprise the planning, routing scheduling , dispatching and follow up functions in the production process so organized that the movements of material, performance of machines and operation of labor, however subdivided are directed and coordinated as to quantity, time and place."

Conclusively, production planning may be defined in the words that "It is the predetermination of manufacturing requirements such as available materials, money, men, order, priority, production process etc. within the scope of Industrial unit for efficient production of goods to cope with its sale requirements.

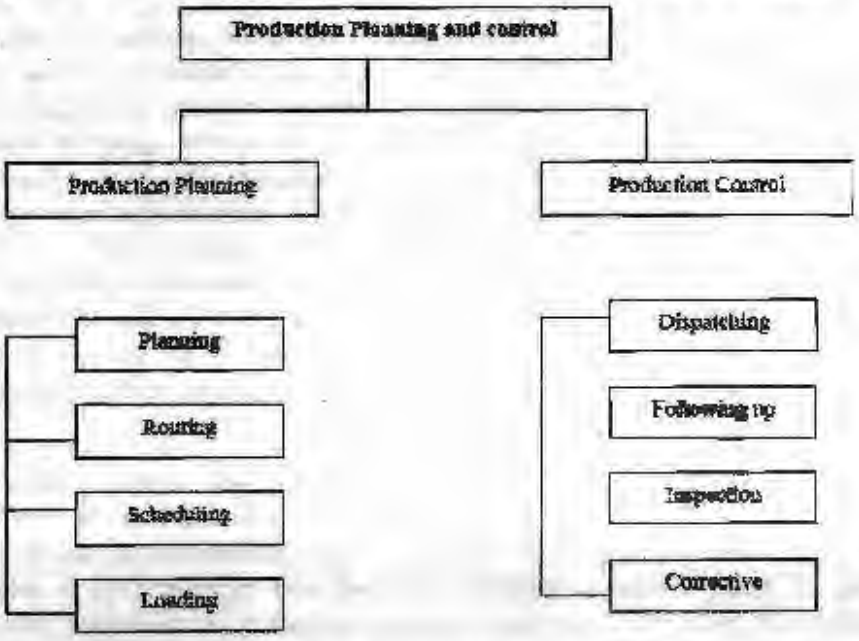
Production planning mainly depends on the type of manufacturing plants which can be divided into two categories: (a) Continuous type of manufacturing plants such as rayon, yarn, shoes, paper plants etc. and (b) Intermitted type of manufacturing plants such as Engineering type of plants and also repetitive type of industries-automobiles, typewriters etc.

Production planning without production control is like a bank without a bank manager, planning initiates action while control is an adjusting process, providing corrective measures for planned development. Production control regulates and stimulates the orderly how of materials in the manufacturing process from the beginning to the end.

Main functions of production planning and control includes planning, routing, scheduling, dispatching and follow-up.

## 1.6 STEPS OF PRODUCTION PLANNING AND CONTROL

Production Planning and Control (PPC) is a process that comprises the performance of some critical; functions on either side, viz., planning as well as control.




Production Planning and Control Process

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## 1.7 PRODUCTION PLANNING:

Production planning may be defined as the technique of foreseeing every step in a long series of separate operations, each step to be taken at the right time and in the right place and each operation to be performed in maximum efficiency. It helps entrepreneur to work out the quantity of material manpower, machine and money requires for producing predetermined level of output in given period of time.

Planning is deciding in advance what to do, how to do it, when to do it and who is to do it. Planning bridges the gap from where we are, to where we want to go. It makes it possible for things to occur which would not otherwise happen.

Routing:

Under this, the operations, their path and sequence are established. To perform these operations the proper class of machines and personnel required are also worked out. The main aim of routing is to determine the best and cheapest sequence of operations and to ensure that this sequence is strictly followed. In other words, routing may be defined as the selection of path which each part of the product will follow, which being transformed from raw material to finished products. Routing determines the most advantageous path to be followed from department to department and machine to machine till raw material gets its final shape. In small enterprises, this job is usually done by entrepreneur himself in a rather adhoc manner. Routing procedure involves following different activities.

1) An analysis of the article to determine what to make and what to buy.
2) To determine the quality and type of material
3) Determining the manufacturing operations and their sequence.
4) A determination of lot sizes
5) Determination of scrap factors
6) An analysis of cost of the article
7) Organization of production control forms.

Scheduling:

Scheduling determines the programme for the operations. Scheduling may be defined as 'the fixation of time and date for each operation' as well as it determines the sequence of operations to be followed. It means working out of time that should be required to perform each operation and also the time necessary to perform the entire series as routed, making allowances for all factors concerned. It mainly concerns with time element and priorities of a job. The pattern of scheduling differs from one job to another which is explained as below:

Production schedule: The main aim is to schedule that amount of work which can easily be handled by plant and equipment without interference. Its not independent decision as it takes into account following factors.

- Physical plant facilities of the type required to process the material being scheduled.
- Personnel who possess the desired skills and experience to operate the equipment and perform the type of work involved.
- Necessary materials and purchased parts.

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Master Schedule: Scheduling usually starts with preparation of master schedule which is weekly or monthly break-down of the production requirement for each product for a definite time period, by having this as a running record of total production requirements the entrepreneur is in better position to shift the production from one product to another as per the changed production requirements. This forms a base for all subsequent scheduling acclivities. A master schedule is followed by operator schedule which fixes total time required to do a piece of work with a given machine or which shows the time required to do each detailed operation of a given job with a given machine or process.

Manufacturing schedule: It is prepared on the basis of type of manufacturing process involved. It is very useful where single or few products are manufactured repeatedly at regular intervals. Thus it would show the required quality of each product and sequence in which the same to be operated.

Scheduling of the Job order manufacturing:

Scheduling acquires greater importance in the job order manufacturing. This will enable the speedy execution of job at each center point. As far as small scale industry is concerned scheduling is of utmost importance as it brings out efficiency in the operations and reduces cost price. The small entrepreneur should maintain four types of schedules to have a close scrutiny of all stages namely an enquiry schedule, a production schedule, a shop schedule and an arrears schedule out of above four, a shop schedule is the most important most suited to the needs of small scale industry as it enables a foreman to see at a glance.

- The total load on any section
- The operational sequence
- The stage, which any job has reached.

Loading:

The next step is the execution of the schedule plan as per the route chalked out it includes the assignment of the work to the operators at their machines or work places. So loading determines who will do the work as routing determines where and scheduling determines when it shall be done. Gantt Charts are most commonly used in small industries in order to determine the existing load and also to foresee how fast a job can be done. The usefulness of their technique lies in the fact that they compare what has been done and what ought to have been done. Most of a small scale enterprise fail due to non-adherence to delivery schedules therefore they can be successful if they have ability to meet delivery order in time which no doubt depends upon production of quality goods in right time. It makes all the more important for entrepreneur to judge ahead of time what should be done, where and when thus to leave nothing to chance once the work has begun.

## PRODUCTION CONTROL:

Production control is the process of planning production in advance of operations, establishing the extract route of each individual item part or assembly, setting, starting and finishing for each important item, assembly or the finishing production and releasing the necessary orders as well as initiating the necessary follow-up to have the smooth function of the enterprise. The production control is of complicated nature in small industries. The production planning and control department can function at its best in small scale unit only when the work manager, the purchase manager, the personnel manager and the financial controller assist in planning pro-

duction activities. The production controller directly reports to the works manager but in small scale unit, all the three functions namely material control, planning and control are often performed by the entrepreneur himself production control starts with dispatching and ends up with corrective actions.

NOTES

**Dispatching** is concerned with the starting the processes. It gives necessary authority so as to start a particular work, which has already been planned under 'Routing' and 'Scheduling'. Therefore, dispatching is 'release of orders and instruction for the starting of production for any item in acceptance with the route sheet and schedule charts',

Dispatching involves issue of production orders for starting the operations. Necessary authority and conformation is given for:

1. Movement of materials to different workstations.
2. Movement of tools and fixtures necessary for each operation.
3. Beginning of work on each operation.
4. Recording of time and cost involved in each operation.
5. Movement of work from one operation to another in accordance with the route sheet.
6. Inspecting or supervision of work

Dispatching is an important step as it translates production plans into production. **Follow up:** Every production programme involves determination of the progress of work, removing bottlenecks in the flow of work and ensuring that the productive operations are taking place in accordance with the plans. It spots delays or deviations from the production plans. It helps to reveal defects in routing and scheduling, misunderstanding of orders and instruction, under loading or overloading of work etc. All problems or deviations are investigated and remedial measures are undertaken to ensure the completion of work by the planned date.

**Inspection:** This is mainly to ensure the quality of goods. It can be required as effective agency of production control.

**Corrective measures:** Corrective action may involve any of those activities of adjusting the route, rescheduling of work changing the workloads, repairs and maintenance of machinery or equipment, control over inventories of the cause of deviation is the poor performance of the employees. Certain personnel decisions like training, transfer, demotion etc. may have to be taken. Alternate methods may be suggested to handle peak loads.

## 6. QUALITY CONTROL:

Quality Control (QC) may be defined as 'a system that is used to maintain a desired level of quality in a product or service'. It is a systematic control of various factors that affect the quality of the product. Quality control aims at prevention of defects at the source, relies on effective feed back system and corrective action procedure.

Quality control can also be defined as 'that industrial management technique by means of which product of uniform acceptable quality is manufactured'. It is the entire collection of activities which ensures that the operation will produce the optimum quality products at minimum cost.

The main objectives of quality control are:

- To improve the companies income by making the production more acceptable to the customers i.e., by providing long life, greater usefulness, maintainability, etc.
- To reduce companies cost through reduction of losses due to defects.
- To achieve interchangeability of manufacture in large scale production.
- To produce optimal quality at reduced price.
- To ensure satisfaction of customers with productions or services of high quality level, to build customer goodwill, confidence and reputation of manufacturer.
- To make inspection prompt to ensure quality control.
- To check the variation during manufacturing.

## 7. MATERIALS MANAGEMENT:

Materials management is that aspect of management function which is primarily concerned with the acquisition, control and use of materials needed and flow of goods and services connected with the production process having some predetermined objectives in view.

The main objectives of materials management are:

- To minimize material cost.
- To purchase, receive, transport and store materials efficiently and to reduce the related cost.
- To cut down costs through simplification, standardization, value analysis, import substitution, etc.
- To trace new sources of supply and to develop cordial relations with them in order to ensure continuous supply at reasonable rates.
- To reduce investment tied in the inventories for use in other productive purposes and to develop high inventory turnover ratios.

## 8. MAINTENANCE MANAGEMENT

In modern industry, equipment and machinery are a very important part of the total productive effort. Therefore, their idleness or downtime becomes are very expensive. Hence, it is very important that the plant machinery should be properly maintained.

The main objectives of maintenance management are:

- To achieve minimum breakdown and to keep the plant in good working condition at the lowest possible cost.
- To keep the machines and other facilities in such a condition that permits them to be used at their optimal capacity without interruption.
- To ensure the availability of the machines, buildings and services required by other sections of the factory for the performance of their functions at optimal return on investment.

## LOCATION ANALYSIS:

The selection of appropriate location depending on the size of the industry can be done in two stages:

a) Evaluation of various geographic areas and the selection of an optimum area.

b) Within each area there is a choice of proper site which can be urban, sub-urban or rural are generally known as industrial zone.

Thus in the process of location analysis, firstly some appropriate geographical area is selected and form that area a proper site is selected for the establishment of the plant. The analysis for the choice of appropriate area and corresponding site is based on a number of measures described below.

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**Measures for the selection of location:** The fundamental object of location analysis is to maximize the profits by minimizing the total cost of production associated with the production process.

**Total costs = Fixed costs + Operational costs**

Fixed costs include expenditure on land, building, machines and other equipments etc. Operational costs are the expenditure incurred on inputs, transformation process and the distribution of output. The contribution of various factors to the total cost will vary form place to place e.g. a possible advantage of cheap labour at some place may be offset by more expenditure on fuel, power, taxes etc. similarly the contribution of various factors also depend on the nature of the product e.g. in oil and chemical products the labour costs represent only a small proportion of total costs whereas it it quite high in garment and textile industries.

Other considerations for the choice of location can be Low interest on loans, special grants, political situation, low rentals, other benefits to encourage investment, attitude of residents towards the industry, living standards etc.

## Consideration of plant location:

In particular, the choice of plant location should be based on following consideration

i) Availability of Raw material
ii) Nearness to the potential market
iii) Location should be near to the source of operating power
iv) Supply of labour
v) Transport and communication facilities
vi) Integration with other group of companies
vii) suitability of land and climate
viii) Availability of housing, other amenities and services
ix) Local building and planning regulations
x) Safety requirements
xi) Other considerations for the choice of location can be

## Factors Responsible for Plant Location Choices:

The physical factors associated with location of an enterprise can have a significant impact on the operations of an enterprise and its costs structure.

These factors can be qualitative as well as quantitative. Qualitative facts can be measured in terms of some qualitative criteria namely adequate, good, significant etc. Quantitative factors can be measured on cost or some other quantitative basis like, labour material, housing, land, transport etc.

Certain factors are of great importance in the case of smaller establishments, whereas, others require careful consideration for large establishments.

*Check Your Progress*

i. What is the principle of production planning and control?
ii. Define Quality Control?
iii. What is Productivity?

According to Dr. Visvesvariaya the decision of plant location should be based on nine M's, namely Money, material, manpower, market, motive power, management, machinery, means of communication and momentum to an early start. In general, "a plant should be located at a place where the inhabitants are interested in its success, the product can be sold profitable and the production cost is minimum.

### Disadvantage of localization:

There are many disadvantages of localization viz

i) Localization leads of accumulation of too many workers at one place making the atmosphere crowdy and unhealthy.

ii) It leads to unbalanced development and unequal distribution of wealth.

iii) It is unsafe in case of war and due to other safety reason.

iv) Local Population becomes economically dependent on the industries of that area and may face financial difficulty when the industries in the area fail in their performance.

v) The market of the product may be over exhausted.

The tendency of localization can be observed in various industries e.g. Localization of jute industry in West Bengal, textile in Bombay and Ahmadabad. But in recent years there appears to be definite trend towards decentralization of business location. Decentralization is an indication that there are many good locations for many industries. Decentralization is taking place both on nationwide scale and within the industrial communities.

## PLANT LAYOUT

Plant layout refers to the arrangement of physical facilities such as machines, equipment, tools, furniture etc. in such a manner so as to have quickest flow of material at the lowest cost and with the least amount of handling in processing the product from the receipt of raw material to the delivery of the final product.

### Objectives of good Plant Layout:

A well designed plant layout is one that can be beneficial in achieving the following objectives:

- Proper and efficient utilization of available floor space
- Transportation of work from one point to another point without any delay.
- Proper utilization of production capacity.
- Reduce material handling costs
- Utilize labour efficiently
- Reduce accidents
- Provide for volume and product flexibility
- Provide ease of supervision and control
- Provide for employee safety and health
- Allow easy maintenance of machines and plant.
- Improve productivity

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## Types of layout:

There are mainly four types of plant layout:

a) Product or line layout

b) Process or functional layout

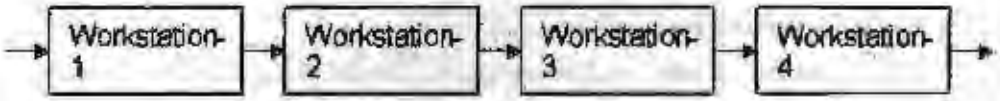
c) Fixed position or location layout

d) Combined or group layout

## PRODUCT OR LINE LAYOUT:

In this type of layout the machines and equipments are arranged in one line depending upon the sequence of operations required for the product. It is also called as line layout. The material moves to another machine sequentially without any backtracking or deviation i.e. the output of one machine becomes input of the next machine. It requires a very little material handling.

It is used for mass production of standardized products.




- Low cost of material handling, due to straight and short route and absence of backtracking.
- Smooth and continuous operations
- Continuous flow of work
- Lesser inventory and work in progress
- Optimum use of floor space
- Simple and effective inspection of work and simplified production control
- Lower manufacturing cost per unit

Disadvantages of Product layout:

- Higher initial capital investment in special purpose machine (SPM)
- High overhead charges
- Breakdown of one machine will disturb the production process.
- Lesser flexibility of physical resources.

PROCESS LAYOUT:

In this type of layout the machines of a similar type are arranged together at one place. This type of layout is used for batch production. It is preferred when the product is not standardized and the quantity produced is very small.


Advantages of Process layout:

- Lower initial capital investment is required.
- There is high degree of machine utilization, as a machine is not blocked for a single product
- The overhead costs are relatively low
- Breakdown of one machine does not disturb the production process.
- Supervision can be more effective and specialized.
- Greater flexibility of resources.

Disadvantages of Process layout:

- Material handling costs are high due to backtracking
- More skilled labour is required resulting in higher cost.
- Work in progress inventory is high needing greater storage space
- More frequent inspection is needed which results in costly supervision

COMBINED LAYOUT:

- A combination of process & product layout is known as combined layout.
- Manufacturing concerns where several products are produced in repeated numbers with no likelihood of continuous production, combined layout is followed

FIXED POSITION OR LOCATION LAYOUT:

Fixed position layout involves the movement of manpower and machines to the product which remains stationary. The movement of men and machines is advisable as the cost of moving them would be lesser. This type of layout is preferred where the size of the job is bulky and heavy. Example of such type of layout is locomotives, ships, boilers, generators, wagon building, aircraft manufacturing, etc.

AIR CRAFT ASSEMBLY

Finished Product

(Aircraft)

Raw material

Machines & Equipments

Labour

NOTES


**Advantages of Fixed position layout:**

- The investment on layout is very small.
- The layout is flexible as change in job design and operation sequence can be easily incorporated.
- Adjustments can be made to meet shortage of materials or absence of workers by changing the sequence of operations.

**Disadvantages of Fixed position layout:**

- As the production period being very long so the capital investment is very high.
- Very large space is required for storage of material and equipment near the product.
- As several operations are often carried out simultaneously so there is possibility of confusion and conflicts among different workgroups.

**PRODUCTIVITY:**

Productivity can be defines as the ration of financial output in a particular interval of time to the financial input in the same time interval. Productivity can be calculated by using the following numerical formula:

Productivity = Financial Efficiency =

$$\frac{\text{Financial output (in a particular interval of time)}}{\text{Financial output (in the same time interval)}}$$

In other words, we can say that productivity defines the quantitative relationship between the output produced and inputs used.

Productivity is a measure of the effective use of resources, usually expressed as the ratio of output to input. It is also called as Efficiency at times. Productivity ratios are used for:

- Planning workforce requirements
- Scheduling equipment
- Financial analysis

NOTES

### FACTORS AFFECTING PRODUCTIVITY:

Productivity stands on four important pillars of Capital, Quality, Management and Technology. These pillars are also responsible for positively as well as negatively affecting the Productivity of the Organization.

1) CAPITAL: An existing machine or facility if it is not functioning up to full capacity or turning out products which are not acceptable can lower productivity. A new machine or repair of existing machine would require capital input.

2) QUALITY: Poor quality products would not meet customer requirements and would need repairs and reworks on the product to meet the standards.

3) MANAGEMENT: With better scheduling, planning, coordinating and controlling activities of management the machine operations can be carried to improve productivity.

4) TECHNOLOGY: Technological improvements have increased productivity. A machine of today would outperform machine of yesterday but may not withstand machines of tomorrow.

## 1.8 WORK STUDY - MEANING AND DEFINITION:

One of the most important techniques, which are frequently employed by all management personnel, is work study. It introduces the most effective method of working. Work study has proved to be the most effective tool in the hands of management. Every industry is facing problems concerning the efficiency at all levels and so a systematic attempt is needed to eliminate unnecessary work and the make remaining work easier. Thus productivity would automatically be increased. It is therefore, necessary to have a constant effort to reduce the waste in every phase of production. So, that there is a surplus available for division to develop good life.

According to the ILO,

> work study is a term used to embrace the techniques of method study and work measurement, which are employed to ensure the best possible use of human and material resources in carrying out s specified activity.

According to British Standards Institute,

> "work study is a generic term for those techniques, particularly 'method study' and 'work measurement', which are used in the examination of human work in all its contexts and which lead systematically to the investigation of all factors which affect the efficiency and economy of the situation being renewed, in order to effect improvement."

Thus, the work study of human works in all aspects in order to improve productivity. It is a systematic and analytical study of work process and work methods with the objective of increasing efficiency and reducing costs. Work study helps to reduce waste through standardization of qualitative and quantitative element of the job.

## 1.9 ADVANTAGES OF WORK STUDY:

Following are the advantages of work study:

1. It helps to achieve the smooth production flow with minimum interruptions.

2. It helps to reduce the cost of the product by eliminating waste and unnecessary operations.

NOTES

3. Better worker-management relations.
4. Meets the delivery commitment.
5. Reduction in rejections and scrap and higher utilization of resources of the organization.
6. Helps to achieve better working conditions.
7. Better workplace layout.
8. Improves upon the existing process or methods and helps in standardization and simplification.
9. Helps to establish the standard time for an operation or job which has got application in manpower planning, and production planning.

## 1.10 Distinction between Manufacturing Operations and Service Operations

Following characteristics can be considered for distinguishing manufacturing operations with service operations:

1. Tangible/Intangible nature of output
2. Consumption of output
3. Nature of work (job)
4. Degree of customer contact
5. Customer participation in conversion
6. Measurement of performance.

Manufacturing is characterized by tangible outputs (products), outputs that customers consume overtime, jobs that use less labor and more equipment, little customer contact, no customer participation in the conversion process (in production), and sophisticated methods for measuring production activities and resource consumption as product are made.

Service is characterized by intangible outputs, outputs that customers consumes immediately, jobs that use more labor and less equipment, direct consumer contact, frequent customer participation in the conversion process, and elementary methods for measuring conversion activities and resource consumption. Some services are equipment based namely rail-road services, telephone services and some are people based namely tax consultant services, hair styling.

CASE STUDY - SHEENA

Sheena had worked for the same Fortune 500 Company for most 15 years. Although the company had gone through some tough times, things were starting to turn around. Customer orders were up, and quality and productivity had improved dramatically from what they had been only a few years earlier due companywide quality improvement program. So, it comes as a real shock to Sheena and about 400 of her co-workers when they were suddenly terminated following the new CEO's decision to downsize the company.

After recovering from the initial shock, Sheena tried to find employment elsewhere. Despite her efforts, after eight months of searching she was no closer to finding a job than the day she started. Her funds were being depleted and she was getting more discouraged. There was one bright spot, though: She was able to bring in a little money by mowing lawns for her neighbors.

*Check Your Progress*

iv. Explain Work Study?

v. What is a combined layout?

She got involved quite by chance when she heard one neighbor remark that now that his children were on their own, nobody was around to cut the grass. Almost jokingly, Sheena asked him how much he'd be willing to pay. Soon Sheena was mowing the lawns of five neighbors. Other neighbors wanted her to work on their lawns, but she didn't feel that she could spare any more time from her job search.

However, as the rejection letters began to pile up, Sheena knew she had to make an important decision in her life. On a rainy Tuesday morning, she decided to go into business for herself taking care of neighborhood lawns. She was relieved to give up the stress of job hunting, and she was excited about the prospects of being her own boss. But she was also fearful of being

completely on her own. Nevertheless, Sheena was determined to make a go of it.

At first, business was a little slow, but once people realized Sheena was available, many asked her to take care of their lawns. Some people were simply glad to turn - the work over to her; others switched from professional lawn care services. By the end of her first year in business, Sheena knew she could earn a living this way. She also performed other services such as fertilizing lawns, weeding gardens, and trimming shrubbery. Business became so good that Sheena hired two part-time workers to assist her and, even then, she believed she could expand further if she wanted to.

**Questions**

1. In what ways are Sheena's customers most likely to judge the quality of her lawn care services?
2. Sheena is the operations manager of her business. Among her responsibilities are forecasting, inventory management, scheduling, quality assurance, and maintenance.

**Product Development Risks**

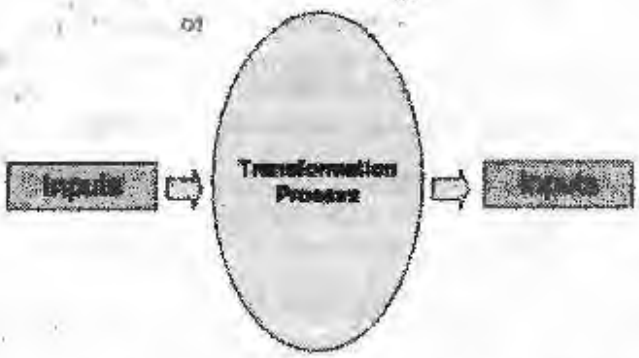
You have the opportunity to invest INR 100 billion for your company to develop a jet engine for commercial aircrafts. Development will span 5 years. The final product costing Rs. 500 million / unit could reach a sales potential, eventually of Rs. 2500 billion. The new engine can be placed in service 5 years from now, but only if it qualifies four years from now for certification clearing commercial use and only if it meets America's Federal Aviation Administration's (FAA) ever tightening standards for noise reduction. Certification also has to be obtained from India's Director General of Civil Aviation (DGCA). There is competition from world-class manufacturers like Pratt and Whitney and Rolls Royce who are developing competing engines. If you decide to proceed with the project, you must also determine where the new engines will be produced and develop the manufacturing facilities. If you decline to proceed, your company could invest its resources elsewhere and based on its track record, get attractive returns.

(a) What would be your line of action?

(b) In case of lengthy product design and development time, what kinds of risks are there?

## 1.11 SUMMARY

Production and Operations Management ("POM") is about the transformation of production and operational inputs into "outputs" that, when distributed, meet the needs of customers.




The process in the above diagram is often referred to as the "Conversion Process". Production and Operations management incorporates many tasks that are interdependent, but which can be grouped under five main headings: Plant, Process, Product, Programme, and People.

## ANSWERS TO 'CHECK YOUR PROGRESS'

(i) The principle of production planning and control lies in the statement 'First Plan Your Work and then Work on Your Plan'.

(ii) Quality Control (QC) may be defined as 'a system that is used to maintain a desired level of quality in a product or service'.

(iii) Productivity can be defines as the ration of financial output in a particular interval of time to the financial input in the same time interval.

(iv) work study is a term used to embrace the techniques of method study and work measurement, which are employed to ensure the best possible use of human and material resources in carrying out s specified activity.

(v) A combination of process & product layout is known as combined layout. Manufacturing concerns where several products are produced in repeated numbers with no likelihood of continuous production, combined layout is followed

## 1.12 TEST YOURSELF

1) What do you mean by Production Management?

2) Describe objectives of Production Management.

3) Briefly discuss the scope of Production Management.

4) Explain various steps of Production Planning and Control.

5) What do you mean by Production Control?

6) What is Location Analysis?

7) Write a short note on:

i) Plant layout

ii) Product layout

iii) Process layout

iv) Productivity

v) Work-study

8) What do you mean by Operation Management?

9) Distinguish between manufacturing operations and service operations.

NOTES

## 1.13 REFERENCES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- **Chase, R. B., Aquilano, N. J., & Jacobs, F. R. (2018). Operations and supply chain management (14th ed.). McGraw-Hill Education.**


## 1.14 FURTHER READING


- *Production and Operations Management by S. Anil Kumar and N. Suresh*
- *Production and Operations Management by S.N. Chary*
- *Operations Management by Jae K. Shim, Joel G. Siegel*

# 2 NEW PRODUCT DEVELOPMENT

NOTES

*The Chapter Covers :*



*Learning Objectives:*

After going through this chapter, you should be able to

- Explain the process
- Clarify service design
- Define opportunity management
- Explain UCD Models and Approaches
- New Product Development Strategies

NOTES

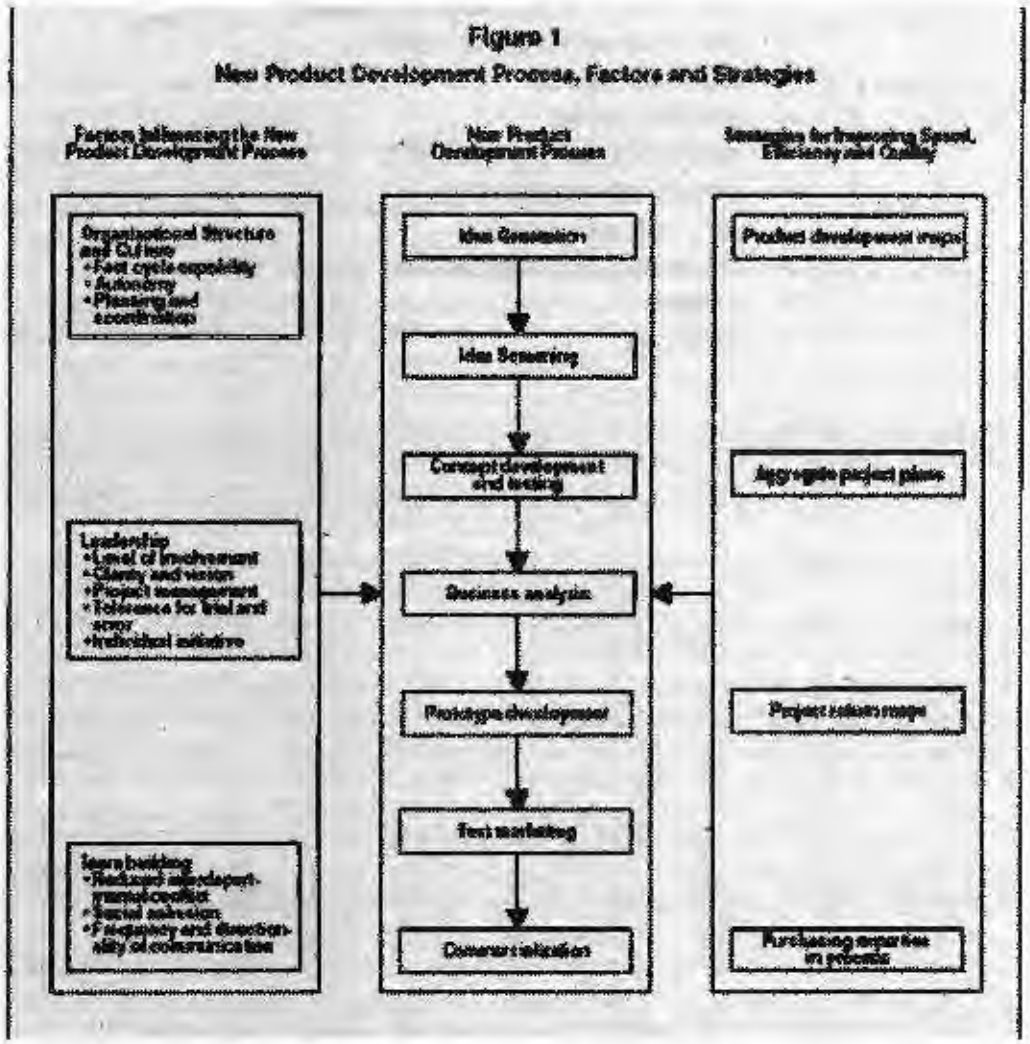
## 2.1 Introduction

In business and engineering, new product development (NPD) is the term used to describe the complete process of bringing a new product to market. A product is a set of benefits offered for exchange and can be tangible (that is, something physical you can touch) or intangible (like a service, experience, or belief). There are two parallel paths involved in the NPD process: one involves the idea generation, product design and detail engineering; the other involves market research and marketing analysis. Companies typically see new product development as the first stage in generating and commercializing new products within the overall strategic process of product life cycle management used to maintain or grow their market share.

## 2.2 The process

Figure 1

New Product Development Process, Factors and Strategies




1. **Idea Generation** is often called the "fuzzy front end" of the NPD process

   - Ideas for new products can be obtained from basic research using a SWOT analysis (Strengths, Weaknesses, Opportunities & Threats), Market and consumer trends, company's R&D department, competitors, focus groups, employees, salespeople, corporate spies, trade shows, or Ethnographic discovery methods (searching for user patterns and habits) may also be used to get an insight into new product lines or product features.

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- Lots of ideas are being generated about the new product. Out of these ideas many ideas are being implemented. The ideas use to generate in many forms and their generating places are also various. Many reasons are responsible for generation of an idea.
- Idea Generation or Brainstorming of new product, service, or store concepts - idea generation techniques can begin when you have done your OPPORTUNITY ANALYSIS to support your ideas in the Idea Screening Phase (shown in the next development step).

2. Idea Screening

The object is to eliminate unsound concepts prior to devoting resources to them. The screeners should ask several questions:

- Will the customer in the target market benefit from the product?
- What is the size and growth forecasts of the market segment/target market?
- What is the current or expected competitive pressure for the product idea?
- What are the industry sales and market trends the product idea is based on?
- Is it technically feasible to manufacture the product?
- Will the product be profitable when manufactured and delivered to the customer at the target price?

3. Concept Development and Testing

- Develop the marketing and engineering details
- Investigate intellectual property issues and search patent data bases
- Who is the target market and who is the decision maker in the purchasing process?
- What product features must the product incorporate?
- What benefits will the product provide?
- How will consumers react to the product?
- How will the product be produced most cost effectively?
- Prove feasibility through virtual computer aided rendering, and rapid prototyping
- What will it cost to produce it?
- Testing the Concept by asking a sample of prospective customers what they think of the idea. Usually via Choice Modeling.

4. Business Analysis

- Estimate likely selling price based upon competition and customer feedback

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- Estimate sales volume based upon size of market and such tools as the Fourt-Woodlock equation
- Estimate profitability and break-even point

5. Beta Testing and Market Testing
   - Produce a physical prototype or mock-up
   - Test the product (and its packaging) in typical usage situations
   - Conduct focus group customer interviews or introduce at trade show
   - Make adjustments where necessary
   - Produce an initial run of the product and sell it in a test market area to determine customer acceptance
6. Technical Implementation
   - New program initiation
   - Finalize Quality management system
   - Resource estimation
   - Requirement publication
   - Publish technical communications such as data sheets
   - Engineering operations planning
   - Department scheduling
   - Supplier collaboration
   - Logistics plan
   - Resource plan publication
   - Program review and monitoring
   - Contingencies - what-if planning
7. Commercialization (often considered post-NPD)
   - Launch the product
   - Produce and place advertisements and other promotions
   - Fill the distribution pipeline with product
   - Critical path analysis is most useful at this stage
8. New Product Pricing
   - Impact of new product on the entire product portfolio
   - Value Analysis (internal & external)
   - Competition and alternative competitive technologies

- Differing value segments (price, value, and need)
- Product Costs (fixed & variable)
- Forecast of unit volumes, revenue, and profit

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These steps may be iterated as needed. Some steps may be eliminated. To reduce the time that the NPD process takes, many companies are completing several steps at the same time (referred to as **concurrent engineering** or **time to market**). Most industry leaders see new product development as a proactive process where resources are allocated to identify market changes and seize upon new product opportunities before they occur (in contrast to a *reactive strategy* in which nothing is done until problems occur or the competitor introduces an innovation). Many industry leaders see new product development as an ongoing process (referred to as *continuous development*) in which the entire organization is always looking for opportunities.

For the more innovative products, great amounts of uncertainty and change may exist, which makes it difficult or impossible to plan the complete project before starting it. In this case, a more flexible approach may be advisable.

Because the NPD process typically requires both engineering and marketing expertise, cross-functional teams are a common way of organizing projects. The team is responsible for all aspects of the project, from initial idea generation to final commercialization, and they usually report to senior management (often to a vice president or Program Manager). In those industries where products are technically complex, development research is typically expensive, and product life cycles are relatively short, strategic alliances among several organizations helps to spread the costs, provide access to a wider skill set, and speeds the overall process.

Also, notice that because engineering and marketing expertise are usually both critical to the process, choosing an appropriate blend of the two is important. People respond to new products in different ways. The adoption of a new technology can be analyzed using a variety of diffusion theories such as the Diffusion of innovations theory.

A new product pricing process is important to reduce risk and increase confidence in the pricing and marketing decisions to be made. Bernstein and Macias describe an integrated process that breaks down the complex task of new product pricing into manageable elements.

**The Path to Developing Successful New Products** points out three key processes that can play critical role in product development: Talk to the customer, Nurture a project culture, and Keep it focused.

## 2.3 FUZZY FRONT END

The Fuzzy Front End is the messy "getting ended" period of new product engineering development processes. It is in the front end where the organization formulates a concept of the product to be developed and decides whether or not to invest resources in the further development of an idea. It is the phase between first consideration of an opportunity and when it is judged ready to enter the structured development process (Kim and Wilemon, 2002; Koen et al., 2001). It includes all

activities from the search for new opportunities through the formation of a germ of an idea to the development of a precise concept. The Fuzzy Front End ends when an organization approves and begins formal development of the concept.

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Although the Fuzzy Front End may not be an expensive part of product development, it can consume 50% of development time and it is where major commitments are typically made involving time, money, and the product's nature, thus setting the course for the entire project and final end product. Consequently, this phase should be considered as an essential part of development rather than something that happens "before development," and its cycle time should be included in the total development cycle time.

Koen et al. distinguish five different front-end elements (not necessarily in a particular order:

1. Opportunity Identification
2. Opportunity Analysis
3. Idea Genesis
4. Idea Selection
5. Concept and Technology Development

The first element is the opportunity identification. In this element, large or incremental business and technological chances are identified in a more or less structured way. Using the guidelines established here, resources will eventually be allocated to new projects.... which then lead to a structured NPPD (New Product & Process Development) strategy. The second element is the opportunity analysis. It is done to translate the identified opportunities into implications for the business and technology specific context of the company. Here extensive efforts may be made to align ideas to target customer groups and do market studies and/or technical trials and research. The third element is the idea genesis, which is described as evolutionary and iterative process progressing from birth to maturation of the opportunity into a tangible idea. The process of the idea genesis can be made internally or come from outside inputs, e.g. a supplier offering a new material/technology, or from a customer with an unusual request. The fourth element is the idea selection. Its purpose is to choose whether to pursue an idea by analyzing its potential business value. The fifth element is the concept and technology development. During this part of the front-end, the business case is developed based on estimates of the total available market, customer needs, investment requirements, and competition analysis and project uncertainty. Some organizations consides this to be the first stage of the NPPD process

The Fuzzy Front End is also described in literature as "Front End of Innovation", "Phase 0", "Stage 0" or "Pre-Project-Activities".

A universally acceptable definition for Fuzzy Front End or a dominant framework has not been developed so far. In a glossary of PDMA, it is mentioned that the Fuzzy Front End generally consists of three tasks: strategic planning, concept generation, and, especially, pre-technical evaluation. These activities are often chaotic, unpredictable, and unstructured. In comparison, the subsequent new product development

process is typically structured, predictable, and formal. The term Fuzzy Front End was first popularized by Smith and Reinertsen (1991 R.G.Cooper (1988)[ describes the early stages of NPPD as a four step process in which ideas are generated (I),subjected to a preliminary technical and market assessment(II) and merged to coherent product concepts(III) which are finally judged for their fit with existing product strategies and portfolios (IV). In a more recent paper, Cooper and Edgett (2008) affirm that vital predevelopment activities include:

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1. Preliminary market assessment.
2. Technical assessment.
3. Source-of-supply-assessment: suppliers and partners or alliances.
4. Market research: market size and segmentation analysis,VoC (voice of the customer) research.
5. Product concept testing
6. Value-to-the customer assessment
7. Product definition
8. Business and financial analysis.

These activities yield vital information to make a Go/No-Go to Development decision.

In the in-depth study by Khurana and Rosenthal front-end activities include:

- product strategy formulation and communication,
- opportunity identification and assessment,
- idea generation,
- product definition,
- project planning, and
- Executive reviews.

Economical analysis, benchmarking of competitive products, and modeling and prototyping are also important activities during the front-end activities.

The outcomes of FFE are the

- mission statement
- customer needs
- details of the selected concept
- product definition and specifications
- economic analysis of the product
- the development schedule

- project staffing and the budget, and a
- Business plan aligned with corporate strategy.

NOTES

In a paper by Husig, Kohn and Huskela (2005) was proposed a conceptual model of Front-End Process which includes early Phases of Innovation Process. This model is structured in three phases and three gates:

- Phase 1: Environmental screening or opportunity identification stage in which external changes will be analyzed and translated into potential business opportunities.
- Phase 2: Preliminary definition of an idea or concept.
- Phase 3: Detailed product, project or concept definition, and Business planning.

The gates are:

- Opportunity screening;
- Idea evaluation;
- Go/No-Go for development.

The final gate leads to a dedicated new product development project. Many professionals and academics consider that the general features of Fuzzy Front End (fuzziness, ambignity, and uncertainty) make it difficult to see the FFE as a structured process, but rather as a set of interdependent activities (e.g. Kim and Wilemon, 2002). However, Husig et al., 2005 argue that front-end not need to be fuzzy, but can be handled in a structured manner. Peter Koen argues that in the FFE for incremental, platform and radical projects, three separate strategies and processes are typically involved. The traditional Stage Gate (TM) process was designed for incremental product development, namely for a single product. The FFE for developing a new platform must start out with a strategic vision of where the company wants to develop products and this will lead to a family of products. Projects for breakthrough products start out with a similar strategic vision, but are associated with technologies which require new discoveries. It is worth mentioning what are incremental, platform and breakthrough products. Incremental products are considered to be cost reductions, improvements to existing product lines, additions to existing platforms and repositioning of existing products introduced in markets. Breakthrough products are new to the company or new to the world and offer a 5-10 times or greater improvement in performance combined with a 30-50% or greater reduction in costs. Platform products establish a basic architecture for a next generation product or process and are substantially larger in scope and resources than incremental projects.

**Product Design**

Product design is the process by which new products are designed and produced. Product design in its basic form is simply coming up with new ideas to improve the efficiency or productivity of existing products or the creation of new ones. This generation of ideas then leads to production. Here, we've outlined some of the steps that take place in order to help give you a better understanding of exactly what product design is:

### Coming Up With the Idea

There are a number of methods employed by product designers to help them come up with ideas. These can be:

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- Needs based- Looking at things that would help make our everyday lives easier by fulfilling a specific task. This can even be building on or improving an existing item.
- Imaginative thinking- Some designers focus more on using their imagination, their own research and observation of the world around them to come up with their product design ideas.

### Bringing the Product to Life

Once the designer has come up with an idea, it's time to put it to the test by creating a prototype. A number of design ideas will be discussed including the materials best suited for the product, the technology required for its production and the way that the product will meet the user's needs.

Once all of the design elements have been addressed, and all necessary refinements have been made, the product will go into production.

### Selling the Product

Once the product has been designed and the important elements of how it should look and feel have been addressed, there are two ways that a product designer may bring the idea to the public. They might decide to sell the product to a client or have been contracted to come up with the idea. That client will then manufacturer the item and sells it to their customers. Or the designer can sell directly to the public, having the item manufactured and marketed themselves.

### New Technology Now Makes the Process Easier

Combining science, art and technology, a product designer comes up with new ideas for items and then goes through the process of making them a tangible, three dimensional items. Today, there are so many different computer programs and other useful tools that help designers make their ideas come to life. From new ways of actually creating items through plastic injection molding techniques to computer software that helps the designer map out how the product will work, now more than ever product designers have a number of tools at hand to help make their ideas become actual items. Nowadays, anyone can come up with a great product design idea and get the help they need to make their product a reality.

Product design is everywhere we turn. From the furniture we sit on to the toys our children play with.

## 2.4 Service Design

Service design is the activity of planning and organizing people, infrastructure, communication and material components of a service in order to improve its quality and the interaction between service provider and customers. The purpose of service design methodologies is to design according to the needs of customers or participants, so that the service is user-friendly, competitive and relevant to the customers. The

backbone of this process is to understand the behavior of the customers, their needs and motivations. Service designers draw on the methodologies of fields such as ethnography and journalism to gather customer insights through interviews and by shadowing service users. Many observations are synthesized to generate concepts and ideas that are typically portrayed visually, for example in sketches or service prototypes. Service design may inform changes to an existing service or creation of new services.

## 2.5 Characteristics of service design

Service design is the specification and construction of technologically networked social practices that deliver valuable capacities for action to a particular customer. Capacity for action in Information Services has the basic form of assertions. In Health Services, it has the basic form of diagnostic assessments and prescriptions (commands). In Educational Services, it has the form of a promise to produce a new capacity for the customer to make new promises. In a fundamental way, services are unambiguously tangible. Companies such as eBay or collectives such as Wikipedia or Source forge are rich and sophisticated combinations of basic linguistic deliverables that expand customers' capacities to act and produce value for themselves and for others. In an abstract sense, services are networked intelligence.

Service design can be both tangible and intangible. It can involve artifacts and other things including communication, environment and behaviors.

Several authors (Eiglier 1979; Normann 2000; Morelli 2002), though, emphasize that, unlike products, which are created and "exist" before being purchased and used, service come to existence at the same moment they are being provided and used. While a designer can prescribe the exact configuration of a product, s/he cannot prescribe in the same way the result of the interaction between customers and service providers, nor can s/he prescribe the form and characteristics of any emotional value produced by the service.

Consequently, service design is an activity that suggests behavioral patterns or "scripts" to the actors interacting in the service, leaving a higher level of freedom to the customers' behavior

## 2.6 New Product Development Strategies

**Design for Six Sigma**

**Design for Six Sigma (DFSS)** is a separate and emerging business-process management methodology related to traditional Six Sigma. While the tools and order used in Six Sigma require a process to be in place and functioning, DFSS has the objective of determining the needs of customers and the business, and driving those needs into the product solution so created. DFSS is relevant to the complex system/product synthesis phase, especially in the context of unprecedented system development. It is process generation in contrast with process improvement.

DMADV, Define - Measure - Analyze - Design - Verify, is sometimes synonymously referred to as DFSS. The traditional DMAIC (Define -Measure - Analyze - Improve - Control) Six Sigma process, as it is usually practiced, which is focused on evolu-

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tionary and continuous improvement manufacturing or service process development, usually occurs after initial system or product design and development have been largely completed. DMAIC Six Sigma as practiced is usually consumed with solving existing manufacturing or service process problems and removal of the defects and variation associated with defects. On the other hand, DFSS (or DMADV) strives to generate a new process where none existed, or where an existing process is deemed to be inadequate and in need of replacement. DFSS aims to create a process with the end in mind of optimally building the efficiencies of Six Sigma methodology into the process before implementation; traditional Six Sigma seeks for continuous improvement after a process already exists.

## 2.7 DFSS as an approach to design

DFSS seeks to avoid manufacturing/service process problems by using advanced Voice of the Customer techniques and proper systems engineering techniques to avoid process problems at the outset (i.e., fire prevention). When combined, these methods obtain the proper needs of the customer, and derive engineering system parameter requirements that increase product and service effectiveness in the eyes of the customer. This yields products and services that provide greater customer satisfaction and increased market share. These techniques also include tools and processes to predict, model and simulate the product delivery system (the processes/tools, personnel and organization, training, facilities, and logistics to produce the product/service) as well as the analysis of the developing system life cycle itself to ensure customer satisfaction with the proposed system design solution. In this way, DFSS is closely related to engineering, operations (solving the Knapsack problem), systems architecture and concurrent engineering. DFSS is largely a design activity requiring specialized tools including: quality function deployment (QFD), axiomatic design, TRIZ, Design for X, design of experiments (DOE),Taguchi methods, tolerance design, Robustification and Response Surface Methodology for a single or multiple response optimization. While these tools are sometimes used in the classic DMAIC Six Sigma process, they are uniquely used by DFSS to analyze new and unprecedented systems/products. A graphical flowchart of common DFSS tools can be seen at DFSS Roadmap. An additional roadmap for the metrics that may be utilized to deploy DFSS on a company-wide level may be seen at DFSS Metrics.

## Flexible Product Development

Flexible product development is the ability to make changes in the product being developed or in how it is developed, even relatively late in development, without being too disruptive. Consequently, the later one can make changes, the more flexible the process is, the less disruptive the change is, the greater the flexibility.

Flexibility is important because the development of a new product naturally involves change from what came before it. Change can be expected in what the customer wants and how the customer might use the product, in how competitors might respond, and in the new technologies being applied in the product or in its manufacturing process. The more innovative a new product is, the more likely it is that the development team will have to make changes during development.

*Check Your Progress*

i. What is product design?
ii. Explain service design?
iii. Define opportunity management?

NOTES

Flexible development counteracts the tendencies of many contemporary management approaches to plan a project completely at its outset and discourage change thereafter. These include Six Sigma, which aims to drive variation out of a process; lean, which acts to drive out waste; and traditional project management and phased development systems (including the popular Stage-Gate model), which encourage upfront planning and following the plan. Although these methodologies have strengths, their side effect is encouraging rigidity in a process that needs flexibility to be effective, especially for truly innovative products.

For more mature product categories, flexibility techniques are not only overly expensive but often unwise. Consequently, flexibility techniques must be used with discretion, for instance, only in the portions of a product likely to undergo change.

When applied to the development of software products, these methods are commonly known as agile software development. However, agile software methods generally rely on special characteristics of the software medium, especially object technologies, which are not available to non-software products. Consequently, flexible product development draws from some of the roots of agile software development but tends to use other tools and approaches that apply beyond the software medium.

Flexible development uses several techniques to keep the cost of change low and to make decisions at the last responsible moment. These techniques include modular architectures to encapsulate change, experimentation and iteration to sample results and check them out with the customer frequently, set-based design to build and maintain options, and emergent processes that develop during a project in response to its needs.

## Quality function deployment

**Quality function deployment (QFD)** is a "method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process.", as described by Dr. Yoji Akao, who originally developed QFD in Japan in 1966, when the author combined his work in quality assurance and quality control points with function deployment used in value engineering.

QFD is designed to help planners focus on characteristics of a new or existing product or service from the viewpoints of market segments, company, or technology-development needs. The technique yields graphs and matrices.

QFD helps transform customer needs (the voice of the customer [VOC]) into engineering characteristics (and appropriate test methods) for a product or service, prioritizing each product or service characteristic while simultaneously setting development targets for product or service.

## Areas of application

QFD is applied in a wide variety of services, consumer products, military needs (such as the F-35 Joint Strike Fighter), and emerging technology products. The technique is also used to identify and document competitive marketing strategies and tactics (see example QFD House of Quality for Enterprise Product Development, at right).

QFD is considered a key practice of Design for Six Sigma (DFSS - as seen in the referenced roadmap). It is also implicated in the new ISO 9000:2000 standard which focuses on customer satisfaction.

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Results of QFD have been applied in Japan and elsewhere into deploying the high-impact controllable factors in Strategic planning and Strategic management (also known as Hoshin Kanri, Hoshin Planning, Acquiring market needs by listening to the Voice of Customer (VOC), sorting the needs, and numerically prioritizing them (using techniques such as the Analytic Hierarchy Process) are the early tasks in QFD. Traditionally, going to the Gemba (the "real place" where value is created for the customer) is where these customer needs are evidenced and compiled.

While many books and articles on "how to do QFD" are available, there is a relative paucity of example matrices available. QFD matrices become highly proprietary due to the high density of product or service information found therein.

## 2.8 Stage gate model

A stage-gate model, also referred to as a phase-gate process, is a project management technique in which an initiative or project (e.g., new product development, process improvement, business change) is divided into stages (or phases) separated by gates. At each gate, the continuation of the process is decided by (typically) a manager or a steering committee. The decision is based on the information available at the time, including the business case, risk analysis, and availability of necessary resources (e.g., money, people with correct competencies). The stage-gate model may also be known as stage-limited commitment or creeping commitment.

### Stages

A common model is composed of the following stages: ideation, preliminary analysis, business case, development, testing, and launch.

A stage-gate model is a conceptual and operational road map for moving a new project from idea to launch - a blueprint for managing the new-product process to improve effectiveness and efficiency.

The traditional stage-gate process has five stages and five gates. The stages are:

1. Scoping
2. Build business case
3. Development
4. Testing and validation
5. Launch

Conventionally, the gates between stages have the same number as the stage following them.

Ahead of this process there is often a preliminary or ideation phase called discovery, and after the 5th stage the process ends with the post-launch review. Major new product projects go through the full five-stage process. Moderate risk projects, in-

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cluding extensions, modification and improvements, use the short XPress version. Very minor changes (e.g. sales force and marketing requests) may be executed using a lighter process (stage-gate lite). Each stage consists of a set of prescribed, cross-functional, and parallel activities undertaken by a team of people from different functional areas. Stages have a common structure and consist of three main elements: a) Activities, b) Integrated Analysis, and c) Deliverables. Activities consist mainly in information gathering by the project team to reduce key project uncertainties and risks. An integrated analysis of the results of the activities is undertaken by the project team. Deliverables of stages are the results of integrated analysis that are used as input for the next Gate.

## Gates

Gates provide various points during the process where an assessment of the quality of an idea is undertaken. It includes three main issues:

- *Quality of execution:* Checks whether the previous step is executed in a quality fashion.
- *Business rationale:* Does the project continue to look like an attractive idea from an economic and business perspective.
- *Action plan:* The proposed action plan and the requested resources reasonable and sound.

A gate meeting can lead to four results: go, kill, hold, or recycle.

Gates have a common structure and consist of three main elements:

- *Deliverables:* What the project manager and team deliver to the decision point. These deliverables are decided at the output of the previous gate, and are based on a standard menu of deliverables for each gate.
- *Criteria:* Questions or metrics on which the project is judged in order to determine a result (go/kill/hold/recycle) and make a prioritization decision.
- *Outputs:* Results of the gate review-a decision (go/kill/hold/recycle), along with an approved action plan for the next gate, and a list of deliverables and date for the next gate.

## The stages in detail

### Stage 0: Discovery

Deciding what projects the company wants and is capable to pursue. During this stage it is common for companies to take part in idea generation activities such as brain-storming or other group thinking exercises. Once the idea generation team has selected a project that they would like to go forward with, it must be passed on to the first gate and therefore screened by the organization's decision makers.

When searching for new product ideas it is beneficial for an organization to look to the outside world to suggest business opportunities. Using methods such as those found in empathic design can be quite helpful. Communicating with customers to

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understand how and why they use products can produce great strides in idea generation. Specifically, communicating with lead users can provide great feedback to the developers, as these customers are most likely to feel most passionately about the product. In addition to communication with lead users, it may be helpful for developers to communicate with suppliers. By understanding all of the types of business that their materials are being used for, developers may be able to act upon previously untapped possibilities.

### Stage 1: Scoping

The second stage of the product development process is scoping. During this step the main goal is to evaluate the product and its corresponding market. The researchers must recognize the strengths and weaknesses of the product and what it is going to offer to the potential consumer. The competition must also be evaluated during this stage. It is important for the researchers to understand who and what is already in the market as well as what can potentially be developed. By determining the relative level of threat from competitors, the management team will be able to recognize whether or not they should go forward with the production of the product.

### Stage 2: Building the business case and plan

Once the new product passes through gate one after the scoping phase, the next phase in the stage-gate model is building the business case and plan. This stage is the last stage of concept development where it is crucial for companies to perform a solid analysis before they begin developing the product. In comparison to the other stages in the stage-gate model this phase is generally difficult, complex, and resource-intensive. However, companies must put forth a strong effort in this stage for it is directly related to the success and development of a new product. There are four main steps that comprise this stage: product definition and analysis, building the business case, building the project plan, and feasibility review.

### Product definition and analysis

The first step, product definition and analysis, is composed of a series of activities that will provide the information to define and justify the development of a new product. One of the first of these activities is the user needs and wants study where customer value is determined. This addresses questions about the product such as what benefits does the product provide and what features should the product have. During this time the company should conduct surveys and interviews with existing and potential customers, along with staff members. Next, the company must conduct a market analysis. They must determine the market size and segmentation, rate of growth, customer trends and behavior, and what channels reach these customers. Once the market analysis is complete the company must then conduct a competitive analysis. It is important to know how your competitors operate in addition to their strengths and weaknesses. This will not only help you build a great product, but will also help in determining how and where to launch your new product. Together these activities will help define the product and provide a foundation for the marketing strategy. Next, the company must build a technically feasible product concept, which includes the substance and methods needed to produce the new product. Once this is completed the company can then produce a production and operations cost analysis along with a market and launch costs analysis. Next, the company can begin to test the concept they have developed. This is when early prototypes are

developed and presented to staff and consumers to gain feedback and gauge customer reaction. From this the company can make the necessary changes and see the sales potential of the product. This feedback will also help the company build a solid product definition. Lastly, the company will then conduct the business analysis, risk analysis, and financial analysis of the new product.

***Building the business case***

The business case is a document that defines the product and provides the rationale for developing it. This document will vary in format amongst companies, but the primary components are the following: results of the activities of product definition and analysis; legal and regulatory requirements; safety, health, and environmental considerations; assumptions needed to draw the conclusions made, and why it is believed they are valid and reasonable; and out-of-bounds criteria that indicate certain changes/events which will mandate an emergency business case review. This document will be referred to throughout the development process and edited when necessary.

***Building the project plan***

The project plan includes: a scheduled list of tasks and events along with timelines for milestones throughout the development process; the personnel, time, and financial resources needed to complete the project; and an expected launch date for the release of the new product.

***Feasibility review***

The last step of building the business case and plan is the feasibility review. This is when management, along with other departments of the company, reviews the rationale for pursuing the product. They analyze the information provided by the previous steps in this process to decide whether or not the product should move forward. If it is decided to be pursued then it passes through gate two and moves on to the product development stage.

**Stage 3: Development**

During the development phase of the stage-gate process, plans from previous steps are actually executed. The product's design and development is carried out, including some early, simple tests of the product and perhaps some early customer testing. The product's marketing and production plans are also developed during this stage. It is important that the company adheres to their overall goal of the project, which is reflected in these production and marketing plans. Doing this will allow them to definitively decide who they will market their product to and how they will get the product to that target audience. The development team maps out a realistic timeline with specific milestones that are described as SMART: specific, measurable, actionable, realistic, and time-bound. The timeline is frequently reviewed and updated, helping the team stay on task and giving management information about the product's progress. The development stage is when the product truly builds momentum as the company commits more resources to the project and makes full use of cross-functional teamwork as the marketing, technical, manufacturing, and sales departments all come together to offer their expert opinions. Having a diverse development stage ensures that the product continues to meet the company's technical and financial goals. A diverse team allows specific roles and leadership positions to develop as team members make contributions using their strongest attributes. With members having clearly defined roles, tasks can be performed concurrently ensuring a much more efficient development process. The ultimate deliverable of the development stage is

the prototype, which will undergo extensive testing and evaluation in the next stage of the process.

Stage 4: Testing and validation

The purpose of this stage is to provide validation for the entire project. Areas that will be evaluated include: the product itself, the production/manufacturing process, customer acceptance, and the financial merit of the project. This stage is broken up into 3 phases of testing: near testing, field testing, and market testing.

*Near testing*

The main objective of near testing is to find any bugs or issues with a product. A key point to remember here is that the product is no longer a prototype and that it has almost all the features of the commercial model. Testing will be done initially by in-house staff, and customers and partners who are close to the firm. It is important to ensure that those testing have an understanding of how the product should perform, so they know what it should or shouldn't be doing. Members of the research and development team are usually present to observe the participants using the product and take any notes or data that may be useful.

*Field testing*

Field testing, or beta testing, is done by those who can provide valuable feedback on the product. This usually lasts a long period of time and the participants can include customers, partners, or anyone who is not familiar with the producing company. At this juncture the product fully resembles its planned launch model in all aspects; therefore the participants' interaction rate will be higher because they know all the features and benefits. During this phase there are three primary objectives to be achieved. The first objective is to see how much the participant is interested. It is also worthwhile to note which individual attribute they prefer and if they would buy the product. Next, determine how the customer uses the product and evaluate its durability. Confirm the environment in which the customers will be using the product. Recording and analyzing customer feedback is the final step in the field testing phase. This feedback may be used to help inform any minor design improvements that need to be made. The sales and marketing team will also be a beneficiary of field testing feedback; they can use this information to help focus their sales presentation.

*Market testing*

The last phase of the testing and validation stage is market testing. Unlike the other two phases, this one is considered optional. A solid marketing and launch plan along with confidence in the product's ability to sell helps to inform the key decision makers at the test and validation gate. If there is any uncertainty in the marketing or launch plans there are two options to consider. First, a simulated market test may be run, in which customers will be exposed to new products in a staged advertising and purchasing situation. The goal of this test is to obtain an early forecast of sales and make any necessary adjustments to the marketing plan. The second test involves trial sales, and is done through specific channels, regions, or consumer demographics.

Stage 5: Product launch

The product launch is the fifth and final stage of the stage-gate process and is the culmination of the product having passed all previous gates. The producer must come up with a marketing strategy to generate customer demand for the product. The producer must also decide how large they anticipate the market for a new product to be and thus determine the size of their starting volume production. Part

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of the launch stage is training sales and support personnel to be familiar with the product so that they can assist in sales of this product. Setting a product price is an aspect of the product launch that the producer must consider. They should avoid either undershooting or overpricing the potential market. Finally, distribution is a major decision making part of the launch process. Selecting a distributor or value-added reseller for a product must be done with careful though and potential sales in mind.

Having a smooth launch process that includes effective marketing and a knowledgeable and prepared sales force may result in faster time to profit due to early customer acceptance.

## 2.9 Effective gating

Most firms suffer from having far too many projects in their product development pipelines, for the limited resources available. "Gates with teeth" help to prune the development portfolio of weak projects and deal with a gridlocked pipeline. Also, a robust innovation strategy, coupled with strategic buckets, refocuses resources on high value development initiatives.

Note that gates are not merely project review points, status reports or information updates. Rather, they are tough decision meetings, where the critical go/kill and prioritization decisions are made on projects. Thus the gates become the quality control check points in the process ensuring that you do the right projects and also do the projects right.

Gates must have clear and visible criteria so that senior managers can make go/kill and prioritization decisions objectively. Most importantly, these criteria must be effective-that is, they must be operational (easy to use), realistic (make use of available information) and discriminating (differentiate the good projects from the mediocre ones). These criteria can be:

- *Must meet:* Knock-out questions in a check list, designed to kil poor projects outright
- *Should meet:* Highly desirable characteristics which are rated and added in a point-count scheme

A sample list of criteria is shown below, from which a scorecard can be developed that can then be used to score projects at a gate meeting.

- **Must meet** (checklist - yes/no)
  - Strategic alignment (fits business unit strategy)
  - Reasonable likelihood of technical feasibility
  - Meet EH&S policies
  - Positive return versus risk
- **Should meet** (scored on 0-10 scale)
  - Strategic
    - Degree to which projects aligns with business unit strategy
    - Strategic importance
  - Product advantage
    - Unique benefits

NOTES

- Meets customer needs better than existing or competing product
- Value for money
- Market attractiveness
  - Market size
  - Market growth
  - Competitive situation
- Synergies (leverages core competencies)
  - Marketing synergies
  - Technological synergies
  - Manufacturing / processing synergies
- Technical feasibility
  - Technical gap
  - Complexity
  - Technical uncertainty
- Risk versus return
  - Expected profitability (e.g., net present value)
  - Return (e.g., internal rate of return)
  - Payback period
  - Certainty of return

If the answers were "no" or "low" to any of these questions, the decision certainly would not be to kill the project - hence they're poor go/kill criteria.

## 2.10 Advantages and disadvantages

There are a number of advantages to using the stage-gate model for product development, which typically result from its ability to identify problems and assess progress before the project's conclusion. Poor projects can be quickly rejected by disciplined use of the model. When using the stage-gate model on a large project, the model can help reduce complexity of what could be a large and limiting innovation process into a straightforward rule-based approach. When a stage-gate model incorporates cost and fiscal analysis tools such as net present value, the organization can potentially be provided with quantitative information regarding the feasibility of developing potential product ideas. Finally, the stage-gate model is an opportunity to validate the updated business case by a project's executive sponsors.

One problem with the stage-gate process is the potential for structural organization to interfere with creativity, as overly structured processes may cause creativity to be reduced in importance.

The stage-gate process needs to be modified to include a top-down link to the business strategy if applied to software and other non-product development projects.

## 2.11 Opportunity Management

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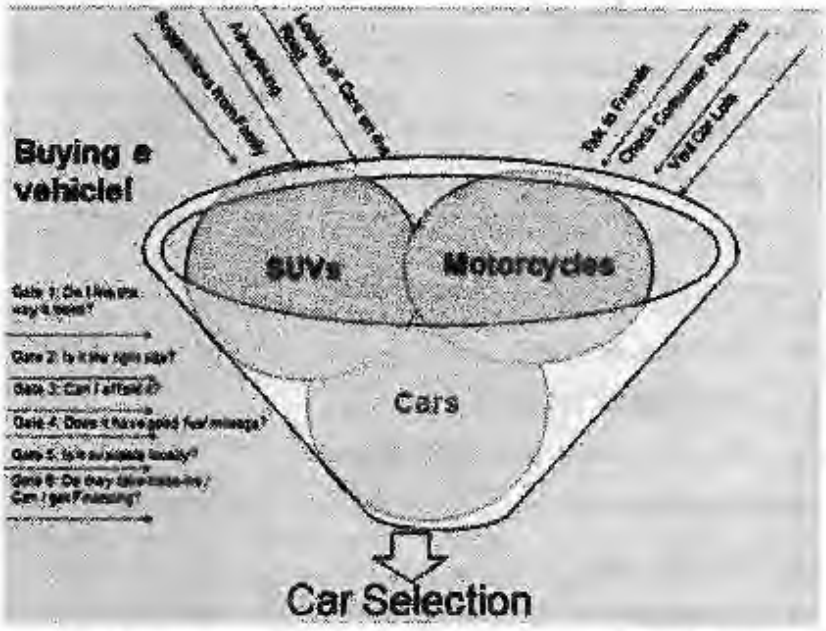


The opportunity management funnel is a visual representation of stage-gate decision making. Opportunity management has been defined as "a process to identify business and community development opportunities that could be implemented to sustain or improve a local economy." The components of opportunity management are:

1. Identifying opportunities.
2. Evaluating and prioritizing these opportunities - This may involve developing criteria, deliberating, and ranking the alternatives.
3. Driving opportunities - Involves assigning leads, accountability, action plans, and project management
4. Constant monitoring - May require one of the following actions:
   - Advance - Commit additional resources to move the idea forward
   - Rework - More investigation/ rethinking
   - Kill - Stop working on the idea and move on

The goal of the opportunity management funnel is to eliminate weak or bad ideas before money or resources are contributed to realize these opportunities. The benefit if the opportunity management funnel when utilizing stage-gate decision making is that the funnel generates efficiencies where weak ideas are efficiently eliminated leaving a strong set of viable alternatives. To fulfill its mandate, the opportunity management funnel filters the broadest range of opportunities and ensures that all priority sectors are represented. When selecting which opportunities to filter through the process, economic developers should be aware that initially, there are no bad ideas or limits. The unviable alternatives will be filtered out throughout the process using stage-gate decision making process

## 2.12 User Centered Design

In broad terms, user-centered design (UCD) is a design philosophy and a process in which the needs, wants, and limitations of end users of a product are given extensive

attention at each stage of the design process. User-centered design can be characterized as a multi-stage problem solving process that not only requires designers to analyze and foresee how users are likely to use a product, but also to test the validity of their assumptions with regards to user behavior in real world tests with actual users. Such testing is necessary as it is often very difficult for the designers of a product to understand intuitively what a first-time user of their design experiences, and what each user's learning curve may look like.

NOTES

The chief difference from other product design philosophies is that user-centered design tries to optimize the product around how users can, want, or need to use the product, rather than forcing the users to change their behavior to accommodate the product.

## 2.13 UCD models and approaches

For example, the user-centered design process can help software designers to fulfill the goal of a product engineered for their users. User requirements are considered right from the beginning and included into the whole product cycle. These requirements are noted and refined through investigative methods including: ethnographic study, contextual inquiry, prototype testing, usability testing and other methods. Generative methods may also be used including: card sorting, affinity diagramming and participatory design sessions. In addition, user requirements can be inferred by careful analysis of usable products similar to the product being designed.

- Cooperative design: involving designers and users on an equal footing. This is the Scandinavian tradition of design of IT artifacts and it has been evolving since 1970.
- Participatory design (PD), a North American term for the same concept, inspired by Cooperative Design, focusing on the participation of users. Since 1990, there has been a bi-annual Participatory Design Conference.
- Contextual design, "customer-centered design" in the actual context, including some ideas from Participatory design

All these approaches follow the ISO standard Human-centered design for interactive systems (ISO 9241-210, 2010).

### Purpose

UCD answers questions about users and their tasks and goals, then uses the findings to make decisions about development and design. UCD of a web site, for instance, seeks to answer the following questions:

- Who are the users of the document?
- What are the users' tasks and goals?
- What are the users' experience levels with the document, and documents like it?
- What functions do the users need from the document?
- What information might the users need, and in what form do they need it?
- How do users think the document should work?

*Check Your Progress*

iv. What is flexible product development?

v. Explain Quality Function Deployment?

NOTES

## Elements

As examples of UCD viewpoints, the essential elements of UCD of a web site are considerations of visibility, accessibility, legibility and language.

## Visibility

Visibility helps the user construct a mental model of the document. Models help the user predict the effect(s) of their actions while using the document. Important elements (such as those that aid navigation) should be emphatic. Users should be able to tell from a glance what they can and cannot do with the document.

## Accessibility

Users should be able to find information quickly and easily throughout the document, regardless of its length. Users should be offered various ways to find information (such as navigational elements, search functions, table of contents, clearly labeled sections, page numbers, color coding, etc). Navigational elements should be consistent with the genre of the document. 'Chunking' is a useful strategy that involves breaking information into small pieces that can be organized into some type meaningful order or hierarchy. The ability to skim the document allows users to find their piece of information by scanning rather than reading. Bold and italic words are often used.

## Legibility

Text should be easy to read. Through analysis of the rhetorical situation, the designer should be able to determine a useful font style. Ornamental fonts and text in all capital letters are hard to read, but italics and bolding can be helpful when used correctly. Large or small body text is also hard to read. (Screen size of 10-12 pixel sans serif and 12-16 pixel serif is recommended.) High figure-ground contrast between text and background increases legibility. Dark text against a light background is most legible.

## Language

Depending on the rhetorical situation, certain types of language are needed. Short sentences are helpful, as well as short, well-written texts used in explanations and similar bulk-text situations. Unless the situation calls for it, do not use jargon or technical terms. Many writers will choose to use active voice, verbs (instead of noun strings or nominals), and simple sentence structure.

## CASE STUDY

Jyoti had given her branded laptop for servicing to an authorized service centre to repair a damaged USB port. The laptop was to be given the next day, but when she went to take it that day, she was told that it was not ready. Jyoti had to wait for four more days before she was finally given her laptop. Because she was in a hurry while receiving the repaired laptop, she did not check the workings of the laptop at that time. On reaching home and switching on the laptop, she noticed that that LCD display had become problematic. The next day, she again went to the service centre and reported the display problem. Jyoti was aghast when she was informed that as she had signed the delivery documents, the service centre cannot take responsibility for the display problem. She was asked to fill up a fresh service requisition form to get the problem rectified and further was told that all expenses incurred in rectifying the problem had to be paid by her.

(a) Do you think that After Sales Service through a third party is a cause for concern? Justify.

(b) There seems to be a breach of trust in the given caselet. How is *breach of trust* related to quality of service?

(c) In the context of the given caselet, formulate a Quality Service Policy to ensure customer satisfaction.

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## 2.14 SUMMARY

New product development can play a variety of roles in defining corporate strategy to gain competitive advantage. This variability makes the process of new product development subject to the emerging organizational issues of the day. In general, a long-run, focused, and ongoing strategic commitment to attractive market opportunities should define the role of new product development. New product development should be integrated into an organizations strategy and significantly contribute to its perpetual renewal. Achieving this integration requires the dedication of intellectual resources at all organizational levels. This intellectual process begins with responsiveness to the business environment.

Turbulent global business environments are the source of new product opportunities and problems for an organization. Consequently, the critical factors defining the organization s market environment for new products must be scanned on a regular basis. In particular, the effects of technology that reduce the life cycles of a firm's products and services must be carefully monitored. For example, the effects of changing information technology will continue to alter the way organizations innovate, design, manufacture, and market new products, as well as the way consumers and other stakeholders respond to those products. They may even redefine markets from traditional channel-dependent institutions to direct, interactive exchanges between buyers and sellers. Consumers may dial up a manufacturer's electronic catalog, send in specifications, and receive a customized product (from flexible manufacturing processes) through an express delivery service in days.

The crux of new product development is identifying the unmet needs of potential buyers and other key market stakeholders as the basis fot defining market opportunities and translating them into core new product concepts. Potential buyers who are affected by turbulent global environments respond largely to their own needs and problems. Identifying the needs of potential buyers and segmenting markets according to those needs is a challenging prospect, but one that enhances new product acceptance. It requires a variety of research approaches that should bring the innovating organization as close to potential buyers as possible. In fact, for many situations, new product development should be viewed as an interactive relationship between the innovating organization and potential buyers (and other key stakeholders) to jointly define and develop the new product. The best way to anticipate market response for a new product is to jointly create it with potential buyers, then estimate when and how many consumers might enter the market to buy.

## ANSWERS TO 'CHECK YOUR PROGRESS'

(i) Product design is the process by which new products are designed and produced. Product design in its basic form is simply coming up with new ideas to improve the efficiency.

(ii) Service design is the activity of planning and organizing people, infrastructure, communication and material components of a service in order to improve its quality and the interaction between service provider and customers.

NOTES

(iii) Opportunity management has been defined as "a process to identify business and community development opportunities that could be implemented to sustain or improve a local economy."

(iv) Flexible product development is the ability to make changes in the product being developed or in how it is developed, even relatively late in development, without being too disruptive.

(v) Quality function deployment (QFD) is a "method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process."

## 2.15 TEST YOURSELF

1. What is New Product Development? Explain in your own words.
2. Explain the various steps of New Product Development Process.
3. What are the various errors that may crop up while selecting a new product idea?
4. Briefly explain the application of QFD in modern day business environment.
5. How important is the design of a product while developing it?
6. Write down the major characteristics of service design.

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## 2.17 FURTHER READING


*Production and Operations Management by S. Anil Kumar and N. Suresh*

*Production and Operations Management by S.N. Chary*

- *Operations Management by Jae K. Shim, Joel G. Siegel*

# 3 INTRODUCTION AND MEANING OF MATERIAL

*The Chapter Covers :*



***Learning Objectives:***

After going through this chapter, you should be able to

- Explain types of materials and material management
- Describe various objectives and scope of material management
- Elucidate functions of material management
- Clarify advantages of material management
- Ways to overcome material management problems

## 3.1 INTRODUCTION

Materials are the most important resources for any company since no goods can be produced without them. Material management controls the procurement, storage amount, movement and consumption of materials that can be used by the company for production process. Materials management is a function, which aims for integrated approach towards the management of materials in an industrial undertaking. Its main objective is cost reduction and efficient handling of materials at all stages and in all sections of the undertaking. Its function includes several important aspects connected with material, such as, purchasing, storage, inventory control, material handling, standardization etc.

According to Bethel, "Material management is the term used to connote controlling the kind, amount, location, movement and timing of various commodities used in and produced by the industrial enterprise."

## 3.2 TYPES OF MATERIALS

The various types of materials to be managed are:

i) **Purchased materials:** They are raw materials, components, spare parts, oils, grease, cotton waste, consumables and tools.

ii) **Work in process (WIP) materials:** These are semi-finished and finished parts and components lying on the shop floor.

iii) **Finished goods:** These are the final products either waiting to be assembled in the assembly lines or in stores which are stocked for final delivery waiting to sell. The various costs involved in these materials are basic price, purchasing costs, inventory carrying cost, transportation cost, materials handling cost, office cost, packing cost, marketing cost, obsolescence and wastages.

## 3.3 MATERIALS MANAGEMENT

### Introduction

Materials Management is simply the process by which an organization is supplied with the goods and services that it needs to achieve its objectives of buying, storage and movement of materials. Materials Management is related to planning, procuring, storing and providing the appropriate material of right quality, right quantity at right place in right time so as to co-ordinate and schedule the production activity in an integrative way for an industrial undertaking. Most industries buy materials, transport them in to the plant, change the materials in to parts, assemble parts in to finished products, sell and transport the product to the customer. All these activities of purchase of materials, flow of materials, manufacture them in to the product, supply and sell the product at the market requires various types of materials to manage and control their storage, flow and supply at various places. It is only possible by efficient materials management.

The materials requirements planning, purchasing, inventory planning, storage, inventory control, materials supply, transportation and materials handling are the activities of materials management. They will be discussed in details in various chapters to follow. About 20-25 years ago, there was no cut-throat competition in the market to sell the various consumer items manufactured by different industrial undertakings and the availability of materials to manufacture these items was not scarce. Therefore, materials management was not thought to be so important and its separate identity in the organization was not felt. But today it has become an important management activity to streamline production. Actually before the production begins it is necessary to ensure availability of all the types of materials

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needed for production and its supply at the various production centers. Planning, purchasing and scheduling are the main functions of materials management. It aims at improved productivity. It is used to reduce the cost, which increases profitability and streamlines the production. Apart from management of material cost and its supply it helps in its proper utilization, transportation, storage, handling and distribution. The market research and forecasting both for sales of company's product and purchasing of various materials required for producing the product are needed at the planning stage.

Purchasing, procurement of materials, transportation, storage, inventory control, quality control and inspection of materials and goods supplied at various production centers before production are also managed as routine work. Materials handling, packaging, warehouse planning, accounting, scrap, surplus and obsolete materials disposal, finished goods safety and care are the activities managed by the materials management department. Selection of personnel for marketing, purchasing, inventory control, stores management and materials handling and their training and placement is also to be seen by the materials management department. This indicates that it is very essential to have a materials management department in any organization to support the management in the production activities. It also helps in the marketing, sales promotion and control of all the types of materials for its quantity, quality and cost.

**Definition**

The International Federation of Purchasing and Materials Management accept the definition of materials management given below. According to it, materials management is a total concept having its definite organization to plan and control all types of materials, its supply, and its flow from raw stage to finished stage so as to deliver the product to customer as per his requirements in time. This involves materials planning, purchasing, receiving, storing, inventory control, scheduling, production, physical distribution and marketing. It also controls the materials handling and its traffic. The materials manager has to manage all these functions with proper authority and responsibility in the material management department. The historical background about the materials management is as follows.

**Historical Background**

The scarcity of materials, which was felt during World War I in USA to a very large extent and it, has become difficult for production managers to supply the War goods. This has created it necessary to organize the Materials Management department for managing large inventories in stores and to analyze the problems arising to control and economize inventory cost problems and shortage elimination. The materials management was included as an important function of the management.

With the development of principles of scientific management by F.W. Taylor in 20th century, the economic use of materials in all the organizations was critically felt to reduce the cost of production.

The early years of developments in the field of materials purchase and supply systematically begins from 1850. Charles Baggage's book on the economy of machinery and manufacturing published in 1832 refers to the importance of purchasing function. Baggage is also known as "Materials Man".

The growth of Rail Road industries by 1866 started in America. The Book on 'The Handling of Railway Supplies and their Purchase and Disposition' in 1887 discussed the purchasing issues. Purchasing gained importance during World War I. Howard T. Lewis was a purchasing professional from 1905 to 1945. He developed importance of sound procurement to company operation.

The concept of materials management was widely spread during World War II. Professor Howard T. Lewis of the Harvard Business School made the extensive studies in Industrial Purchasing Practice. W.N. Michelle, N.F. Harriman, L.F. Buffy, Donald G. Clark, Edward T. Gushee, Russell Forbes, Stuart F. Hewritz and George A. Reward had contributed largely to purchasing and materials management in procuring, receiving, inventory control and supply. World War II introduced a new period in purchasing history. The emphasis on obtaining required and scarce materials influenced a growth in purchasing interest. In 1933, nine colleges offered courses related to purchasing which was increased to forty-nine colleges in 1945 in America. The membership of the National Association of Purchasing Agents increased from 3400 in 1934 to 5500 in 1940. The post-war period saw the development of the value analysis technique, pioneered by General Electric Company in 1947 on the evaluation of which materials or changes in the specification and design would reduce over all product cost. From 1947 to 1960 were 13 years on further developments in materials management. Firms initiated dramatic growth of the materials management during 1960-1970. The Vietnam War resulted in upward price and materials availability pressure. During 1970 Firms experienced widespread materials problems related to 'oil shortages and embargoes'.

Widespread agreement between countries taken place with the overall objective to solve materials problems including materials planning, inventory control, purchasing, quality control, stores control, materials movement and surplus disposal. The purchasing strategies and behaviors that evolved over in 1980 gave rise to foreign global competition.

The global era of trading in between 1970 and 1999 for materials management increased. Purchasing approaches beyond 2000 reflects a changing emphasis towards the improvement of quality of materials, supplier relationship, more co-operative approach, long-term strategies of cost management and database materials management systems for materials planning and utilization in industries to bring about overall improvement in production systems, in-cost reduction through economy and increased sales. In order to serve the corporate goals and perform materials activities efficiently, a functional organization of the materials management must be established to fulfill the objectives of materials program, elimination of materials wastages and duplication of efforts to do so in every organization. Then only the abovementioned goals of materials management can be achieved.

## 3.4 MATERIALS MANAGEMENT ORGANIZATION:

The major resources in any organization to manage are the materials out of seven main resources required to run any organization. They are management, materials, money, man power, machines, methods and matrix or facilities which include systems, plants, location and buildings etc. The purpose of materials management organization in any industry is to plan the materials requirements for the production of goods and services. The structure of the organization must be such so as to have the efficient management of materials controlling its flow, conservation and utilization. Its objective is to use judiciously and economically. The product must be produced from the available materials purchased at the economic price and bring together under one organizational component sharing responsibilities of all the aspects affecting flow, conservation, utilization, quality and cost of materials. Materials management includes inventory management, purchase management, value analysis, store keeping, maintenance and upkeep of the inventories in hand and in process.

Organizational Structure

In Materials following organizational units are relevant:

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- Client - represents the company or the group.
- Company Code - the balance sheet legally independent unit (e.g. individual Ltd.)
- Purchasing Organization - responsible for the procurement.

Note purchasing organizations can:

i) Precisely responsible for the work, across plants for each company code to be active, circular cross or accounting for all plants to be active.

ii) Work - the predisposing and leading stock unit

iii) location - can so that material stocks within a plant contained lead

iv) Recommended storage locations are assigned to a work, so can the number assignment occur more than once.

**Materials planning:**

In the so-called consumption-based planning procurement proposals are based on predefined purchase decisions (e.g., falling below the safety stock), or determined by forecasting calculations. The identified needs will be saved as default. These proposals either be assigned as the responsible purchasing requisitions or given as a planned order in production (PP). Additional Requirements can be captured as a manual purchase requisition.

**Shopping:**

These requisitions are now from shopping in order or be implemented under contracts. In the purchase process will be distinguish whether orders can be made immediately (due to existing agreements such as for example Contracts) or whether is offers must be obtained by means of queries. Procurement is therefore for responsible for a variety of tasks: dealing with inquiries and quotations, supplier selection, order processing, vendor evaluation etc.

**Inventory Management:**

Inventory management has the task of volume, stocks and value to collect timely and accounting for. These include all operations, which the stock of goods change, e.g. Goods receipts and outputs, transfers and stock transfers as well as material reservations and return deliveries. The quantities are in every material movement updated. The value update is normally done an automatic account determination. The system provides hands - Help if for example a goods receipt (GR) with respect to an order to be posted. Here, all relevant data from the system provided.

**Warehouse Management:**

With the warehouse management system watehouse complex structures can be established and monitored. Different methods are of imports and outsourcing support. In WM be leading stock processes such as goods receipts, stock transfers so depicted.

**Audit:**

The audit represents the link between the Materials Management and accounting (FI) Here, Received bills can the reference to a goods receipt (GR), or an order, have fast tracked, checked and then posted. Furthermore be using information from the material master.

Further Settlement depends on several assumptions:

i) much the billing data with pre-planned data, Bookings are done automatically and the invoice is released for payment.

ii) For exceeding specified tolerances, the invoice is for payment blocked

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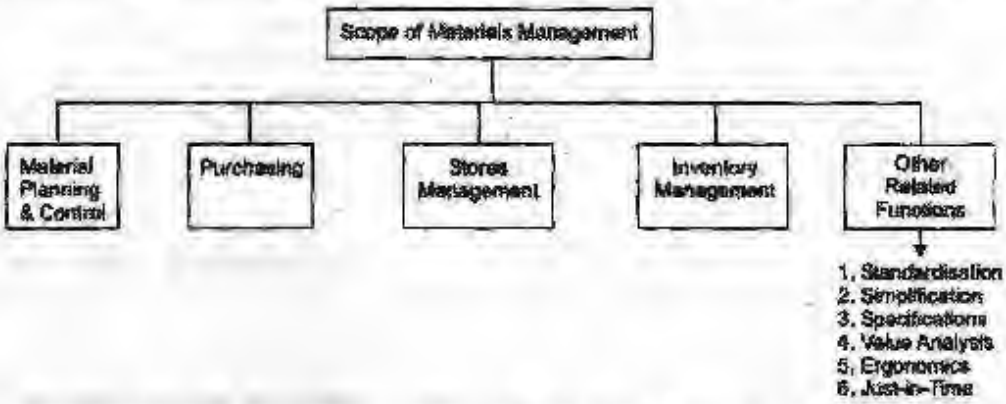
iii) A further possibility is the invoice automatically can be created for goods receipt.

Another important issue is the procurement of marketing. By this is meant that the company has the task of building and care of (possible) long-term relationships with reliable suppliers guarantee supply. Basis for effective cooperation between companies is the advantage that for both partners, so customers and supplier, and is desired by both objective and is.

## 3.5 SCOPE OR FUNCTIONS OF MATERIALS MANAGEMENT:

Materials management is defined as *"the function responsible for the coordination of planning, sourcing, purchasing, moving, storing and controlling materials in an optimum manner so as to provide a pre-decided service to the customer at a minimum cost".*

From the definition it is clear that the scope of materials management is vast. The functions of materials management can be categorized in the following ways:




1) **Materials planning and control:** Based on the sales forecast and production plans, the materials planning and control is done. This involves estimating the individual requirements of parts, preparing materials budget, forecasting the levels of inventories, scheduling the orders and monitoring the performance in relation to production and sales.

2) **Purchasing:** This includes selection of sources of supply finalization in terms of purchase, placement of purchase orders, follow-up, maintenance of smooth relations with suppliers, approval of payments to suppliers, evaluating and rating suppliers.

3) **Stores management or management:** This involves physical control of materials, preservation of stores, minimization of obsolescence and damage through timely disposal and efficient handling, maintenance of stores records, proper location and stocking. A store is also responsible for the physical verification of stocks and reconciling them with book figures. A store plays a vital role in the operations of a company.

4) **Inventory control or management:** Inventory generally refers to the materials in stock. It is also called the idle resource of an enterprise. Inventories represent those items, which are either stocked for sale or they are in the process of manufacturing or they are in the form of materials, which are yet to be utilized. The interval between receiving the purchased parts and transforming them into final products varies from industries to industries depending upon the cycle time of manufacture. It is, therefore, necessary to hold inventories of various kinds to act as a buffer between supply and demand for efficient operation of the system.

Thus, an effective control on inventory is a must for smooth and efficient running of the production cycle with least interruptions.

5) **Other related activities**

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i) **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.

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

iii) **Specifications:** It refers to a precise statement that formulizes the requirements of the customer. It may relate to a product, process or a service.

**Example:** Specifications of an axle block are Inside Dia. = 2 ± 0.1 cm, Outside Dia. = 4 ± 0.2 cm and Length = 10 ± 0.5 cm.

b) **Value analysis:** Value analysis is concerned with the costs added due to inefficient or unnecessary specifications and features. It makes its contribution in the last stage of product cycle, namely, the maturity stage. At this stage research and development no longer make positive contributions in terms of improving the efficiency of the functions of the product or adding new functions to it.

c) **Ergonomics (Human Engineering):** The human factors or human engineering is concerned with man-machine system. Ergonomics is "the design of human tasks, man-machine system, and effective accomplishment of the job, including displays for presenting information to human sensors, controls for human operations and complex man-machine systems." Each of the above functions is dealt in detail.

## 3.6 INTEGRATED CONCEPT OF MATERIALS MANAGEMENT:

Traditionally, various activities related to managing materials were looked after by various departments. While purchases were generally arranged by top management with the assistance of a Purchase Agent or Purchase Officer, store keeping and stock control was the responsibility of the production head with the assistance of a store keeper or Stores Officer. Apart from these two main activities, distribution of materials (mostly finished goods) was the responsibility of marketing.

After realizing the profitability potential of Materials Management function, when attempts were made to exploit this potential, it was realized that there were many problems in achieving the objectives due to inherent conflicts amongst various departmental objectives. When purchasing personnel wants to purchase in bulk to get price discounts, inventory of the stores personnel becomes high.

- The conclusion is that in the traditional set up one person could not be held responsible for all the functions of materials management to achieve overall economy. Therefore necessity of placing all the functions related to materials management e.g. purchasing, stocking, inventory control and distribution under one department headed by an executive of status at par with other departmental heads, was felt.

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- Thus evolved the concept of integrated materials management which can be defined as the function which is responsible for the coordination of planning, selecting sources, purchasing and moving, storing and controlling materials in an optimum manner so as to provide a pre-decided service to the customer at a minimum cost.

### NEED FOR INTEGRATED CONCEPT:

In an integrated set-up, the materials manager is responsible to exercise control and coordinates with an overview that ensures proper balance of conflicting objectives of the individual functions. Integration also helps in the rapid transfer of data, through effective and informal communication channels. This is crucial as the materials management function usually involves handling a vast amount of data. Therefore, integrating the various functions ensures that message channels are shortened and the various functions identify themselves to a common materials management department which, in turn, results in greater co-ordination and better control.

### ADVANTAGES IN INTEGRATED MATERIALS MANAGEMENT CONCEPT:

Organizations which have gone in a big way for the integrated materials management usually enjoy the following advantages:

1) **Better accountability:** Through centralization of authority and responsibility for all aspects of materials function, clear cut accountability is established. This helps in evaluating the performance of materials management in an objective manner.

2) **Better co-ordination:** When a central materials manager is responsible for all functions, the departments under the materials manager create an identity which is common. This results in better support and co-operation in the accomplishment of the materials function. The user departments also find that they have to approach one department for discussing and solving their materials problems. This creates an atmosphere of trust and generally better relations between the user departments and the materials management department.

3) **Better performance:** As all the inter-related functions are integrated organizationally, greater speed and accuracy results in improved communication. Need for materials are promptly brought to notice by materials planning. Purchase department is fed with stock levels and order status by stores and inventory control departments. All this calls for judicious decisions leading to lower costs, better inventory in paper work.

4) **Adaptability to EDP:** The centralization of the materials function has made it possible to design data processing system. All information with regard to materials function is centralized under the integrated materials management function. This has facilitated the collection and analysis of data, leading to better decisions. Advanced and efficient electronic data processing systems can be economically introduced under in integrated set-up.

5) **Miscellaneous advantage:** Under a Centralized Materials Manager, a team spirit is inculcated and this results in better morale and co-operation. The opportunities and exposure available for the individuals for growth and development are better in an integrated set-up.

## 3.7 OBJECTIVES OF MATERIALS MANAGEMENT:

The objectives of integrated materials management can be classified in two categories:

- Primary and
- Secondary.

These are discussed below:

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**Primary Objectives:**

Following may be identified as primary objectives which are to be achieved.

a) To purchase the required materials at minimum possible prices by following the prescribed purchase policies and encouraging healthy competition.

b) To achieve high inventory turnover i.e. to meet materials requirement of the organization by keeping low average stocks so that the capital locked up in materials is turned over a large no of times.

c) To incur minimum possible expenditure on administrative and other allied activities related to purchase of materials and also to keep the materials in stock till they are finally delivered to the users.

d) To ensure that continuity of supply of materials to the users is maintained by avoiding out of stock situation.

e) To supply materials of consistent quality i.e. of quality which meets user specification and it is fit for service.

f) To keep the wage bill of the department low by ensuring proper distribution of work among staff and not employing surplus staff.

g) To maintain good relationship with the suppliers of materials and also develop new suppliers for the products for which reliable suppliers do not exist.

h) To ensure training and development of personnel employed in the department so that good industrial relations are maintained.

i) To maintain proper and up-to-date records of all stores transactions and purchases.

**Secondary Objectives:**

a) To assist technical/design department in developing new materials and products this may be more profitable to the organization.

b) To make economic 'make or buy' decisions.

c) To ensure standardization of materials

d) To contribute in the product improvement.

e) To contribute in the development of inter departmental harmony.

f) To follow scientific methods of forecasting prices and future consumption of materials.

*Check Your Progress*

i. What is material management?

ii. What are various types of materials?

iii. What is ordering cost?

## 3.8 ADVANTAGES OF MATERIALS MANAGEMENT:

1) Material management has created a niche in many organizations, which have implemented the integrated materials management. These organizations usually enjoy the following advantages:

2) Better accountability on part of materials as well as other departments as no one can shift blame to others.

3) As materials management is handled by single authority, it can result in better coordination, as it becomes the central point for any material related problems.

4) Materials management department makes sure that better quality material is supplied timely to the requesting departments. This can result in better performance of the organization.

5) A materials management system is typically controlled through an information system, thus, can help in taking decisions related to material in the organization.

6) One indirect advantage of material management is that good quality material develops the ethical and moral standard in an organization. However, please note there is no study on this issue.

## 3.9 OVERCOMING MATERIALS MANAGEMENT PROBLEMS

Materials management is concerned with planning, organization, and control of materials inventory, production, stocking, and distribution. In the 1990s, both the economic and industrial environments are dynamic. Thus, materials management practices and procedures must be capable of supporting effective decision-making in these dynamic environments.

The growing internationalization of business activity further complicates the process of materials management, in terms of

- Developing accurate and timely data on production and stocking levels,
- Developing and projecting accurate and timely data on material and product requirements, and
- Incorporating a wide variety of multinational and international economic data into materials management activities.

The growing internationalization of business activity has been accompanied by the introduction of high technology (high tech) procedures into manufacturing processes. With respect to materials management, the greatest significance of the introduction of high tech procedures into manufacturing processes has been the development of the just in time (JIT) materials processing procedure. The widespread application of the JIT procedure will not only contribute to revolutionary change in the processes of manufacturing, it will also usher in revolutionary change in manufacturing support procedures and processes, such as materials management.

**Cost involved in Material Management:**

Managing material involves various costs that are:

- **Basic:** Cost of materials paid by a company to a supplier.
- **Government levies and taxes:** Cost paid to the government such as exercise duty, sales tax etc by a company.
- **Ordering:** Costs such as tendering, stationary, postage, receiving, inspection and bill payment, staff and the delivery that incurred while purchasing material.
- **Inventory carrying:** Costs such as losses due to deterioration of materials, insurance premium and storage and preservation expenditure that incurred for maintaining inventory of materials.

- Packaging: Cost that incurred while packaging the products.
- Material handling: Cost that incurred while moving and storing the materials.
- Shipment: Cost that incurred while transporting materials from suppliers to buyers.
- Insurance: Premium cost that incurred for insuring materials.

In addition to this cost, there are certain costs that occur due to the defects in designing product, poor quality of material, rework and rejection of product during inspection.

## 3.10 Functions of Materials Management

(I) Primary Functions

To meet the primary objectives, the primary functions of the materials management are given as follows:

*(i) Materials Requirements Planning (MRP)*

Planning of materials requirements in manufacturing is a necessary function in any organization, as inventory of materials involves about 60% of the total investment of the organization. The profit earned depends on the utilization of these materials and reducing the inventory of the materials.

The latest technique used is called Just in Time (JIT) is referred practically to no inventory.

However, in the present situations in any of the organization particularly manufacturing organization, it is not absolutely possible to keep no inventory of materials required for production.

The MRP is a technique used to plan the materials starting from the raw materials, finished parts, components, sub-assemblies and assemblies as per Bill of Materials (BOM) to procure or produce them to support a Master Production Schedule (MPS). It is used on computers productively by any company that uses a MPS to manufacture products that require assemblies, components and materials to produce the final products. The MPS is exploded using the bills of materials to determine requirements of lower-level assemblies, components, finished parts and raw materials. It plans orders to meet these needs.

*(ii) Purchasing*

All the organizations need an efficient and economic purchasing and procurement of its various supplies of materials from the suppliers. The materials management department has to perform this function of purchasing and procurement of materials very efficiently. Since 50% to 60% of sales turnover is spent on the purchase of various materials, the amount of profit earned on this sale very much depends how economically the materials are purchased and utilized in the organization. The profitability depends on the efficiency by which this particular function of purchasing and procuring the requisite materials at appropriate time will be done and its availability is assured.

The function of purchasing can be stated as follows:

(1) The requisition of material is necessary by proper authority to initiate its purchase.

(2) To select proper supplier for the materials requisitioned, before placing an order.

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(3) To negotiate about the price of the material from the supplier and it will be purchased at the cheapest price.

(4) The quality of material must be assured and should not be compromised with the cost of the material.

(5) The material should be purchased of right quantity and right quality at proper time at the cheapest cost.

(6) To set the proper purchase policy and procedure.

*(iii) Inventory Planning and Control*

The modern concept of inventory planning is that the materials should be purchased and brought in the stores just before it enters the production or sold out so that inventory cost is negligible. The zero inventories are the ideal planning. There are three types of inventories.

(i) Raw materials (ii) Purchased goods (iii) Finished parts and components

The inventory control of these various materials lies with the materials management department, production department and sales department. Inventory at different levels is necessary to make sure about the availability of all these types of materials and goods and their proper flow from one facility to another at different levels of production centers in a manufacturing concern.

The storing of various types of materials and parts as inventory is therefore very essential before its delivery and use at different production centers. This involves inventory planning and control of materials in the stores department. Many a time, the supplier may not be in a position to supply the materials of the ordered quantity at the proper time. To maintain the continuity in production and line balance in assembly work, the various types of inventories are necessary to be maintained and kept in the stores.

The raw materials before being supplied to a production process, some of it is sent to store as inventory and rest is sent to production facility as per its requirements and in the same way, various parts manufactured and assembled as components and assemblies are also stored as finished parts inventories at the different places in the stores. The final products before being supplied to the customers are also stocked as inventory of the final products of the organization to meet the fluctuating demand and to regularise the supplies in the market. Thus, the inventory control is a very important function of the materials management department. The various types of inventory models are developed for the different materials to economise the purchase, supply, inventory control and production control to analyze and optimize the costs involved in ordering, set-up and inventory carrying of materials required in the production.

*(iv) Ascertaining and Maintaining the Flow and Supply of Materials*

Distribution of materials requisitioned by the various production centers and other departments must be ascertained and its flow and continuity of supply must be maintained by the materials management department. Insufficient or zero inventories many times create the situations of stock-outs and leads to stoppage of production. Failure of materials handling devices is also responsible for disruption of material supplies. Alternatives or emergency supply systems can be used for assuring production lines to continue.

Uncertainty in demand and production quantity is the main factor. As the customer requirements as per his needs and liking, are changing very fast. The management has to maintain continuity in production to meet this uncertainty

in demand and control the situation by proper flow of materials supply and distribution at various production facilities and other departments as per changes in production quantity.

*(v) Quality Control of Materials*

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The quality of the product manufactured by the organization depends upon the quality of the materials used to manufacture that product. It is a very important and necessary function of materials management to purchase the right quality of materials. The inspection, quality control, simplification, specification, and standardization are the activities which are to be followed for the measurement of quality of the materials. The quality assurance is decided by inspection and checking the various properties of materials as per their specifications and standard. The size and dimensional measurements within tolerance limits assures the interchangeability and reliability of components and parts.

Quality is largely determined by consumer taste and liking. The market is under buyer's control. Customer decides the quality of the product. Material quality control aims at delivering product at higher and higher quality at lower cost. The product will be specified not only by its dimensional accuracy but its quality standards, durability and dependability, high performance, reliability and aesthetic value. Each of this factor aids cost to the product. In order to achieve high quality, the materials input to the product should be of high quality, which will have higher cost. The performance decides the reliability, which is obtained through high quality production. The performance is checked by quality inspection and accuracy.

This also aids cost to the product. The quality of the materials also decides the selection of vendors and the relationship between buyers and suppliers. The specifications, size and quality of materials must be referred and if possible the standard should be followed for specifications and sizes. The types of tests required for assuring the quality should be specified and conducted to establish the standards.

*(vi) Departmental Efficiency*

The objective of this function is to ensure the efficiency of the system adopted. If the system and procedure adopted for materials management are inefficient or faulty, none of the objectives mentioned above can be fulfilled, howsoever the procedure may be good. In order to maintain the things in proper way as per planning an efficient control is necessary in the department over each and every process. Management Information System (MIS) and feed back control at every stage of working must be adopted to control and make the management and employee work as efficiently as possible to achieve the best results.

(II) Secondary Functions

There can be number of secondary functions. Some of them are discussed below:

*(i) Standardization and Simplification*

The standards and specifications of various types of materials are fixed by design and technical department of the organization and they are followed by production department. Standards define the quality, reduction in sizes and variety, interchangeability of parts and products. It ensures efficient utilization of materials and reduces wastages. Standard materials are always available at reasonable cost. It also helps purchasing department in selection of materials and vendors. If less variety of items purchased and put in the stores the types of inventories will be reduced and in this way the cost of carrying the inventories in the stores will be reduced.

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The objective of this function will be to produce standard product reducing the overall cost of the product.

*(ii) Design and Development of the Product*

The variety in product and functionality are the important factors to promote the sales of a product. The new techniques of designing a product using Computer Aided Design (CAD) has made possible to develop variety of products at faster rate. The new technological development in manufacturing using Computer Aided Manufacturing (CAM) can produce variety of products at much faster rate with all types of flexibility in the manufacturing as compared to conventional methods.

Materials management department has to act according to use of such variety of materials to produce variety of parts and ensure the supply of such materials. It should also be decided how to purchase and produce such variety of products with flexibility and economic cost.

*(iii) Make and Buy Decisions*

These types of decisions are the policy decisions of the management. The capacity of the organization and the various facility developed by the organization to manufacture various items is the main objective of every organization. This is the important planning activity of every undertaking. But when a company grows fast, its sales increases at rapid rate then it becomes an important matter to decide whether the company should buy the parts and components or increase and establish its facilities to cope up with the increased demand and sales. This will be greatly concern to materials management department. It will help in selecting the suppliers to buy the items at reduced cost. The material evaluation, its availability, alternative materials selection, procurement and inventory control are the functions influence the make and buy decisions.

The make and buy decisions are largely based on cost economics and cost benefit analysis made by the organization using the existing production capacity of labor, skill and machines available with the factory and how best they can be utilized.

*(iv) Coding and Classification of Materials*

This is an important function of the materials management to help the production and purchasing department of every organization. It uses its own methods of classification of materials used to manufacture the product or a company selling various goods. ABC analysis is one of the simple and standard methods used by most of the firms for classification and storing their variety of materials.

The materials are recognized to purchase and store as an inventory by its codes and nomenclatures. The various methods of coding are used by every organization to control the variety of materials and its quantity and price rates.

*(v) Forecasting and Planning*

Materials requirements planning are based on correct forecasting of sales and demand of the products in the market. The market fluctuations are to be observed to control production of the organization. The various methods of forecasting are available and the materials management department can choose the one which gives the best results to the company.

Forecast of future demand of sales sets the planning of materials supply. Analytical methods are adopted for systematic forecasting and planning to procure the various materials required for production.

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In case of fluctuating demands, there can be uncertainties in supply as well. This can be overcome by maintaining the proper quantity in inventory of short supply materials at proper time. The different techniques available to use correct forecasting have to be utilized by materials manager to plan the procurement, purchase, supply, managing the outside and inside transport and storing of the materials to maintain the supply chain lines at every production facility to meet the changes in production quantity and schedule of production to meet the fluctuating demand of sales of products manufactured by the organization.

To fulfill the objectives and functions of materials management and control the activities of this department, they are thoroughly studied and analyzed. The topics for this study and analysis are given as follows:

(1) Materials management organization

(2) Materials requirements planning

(3) Forecasting

(4) Purchasing

(5) Inventory control

(6) Storing, warehouse planning and control

(7) Value analysis

(8) Materials handling

(9) Just In Time

The main functions of materials management are summarized as follows:

(1) Materials planning as per production requirements for quantity and time

(2) Purchasing the required materials

(3) Make or Buy decisions

(4) Receipts and inspections of materials

(5) Storage, warehousing securities and preservation

(6) Distribution of materials

(7) Transportation should be expedited and must be economically done

(8) Inventory control

(9) Disposal of over stock, surplus, scrap and salvage of materials

(10) Developing new sources of supply at competitive way

(11) Ancillaries industrial development

(12) Indigenous source of supply for foreign materials

(13) Material cost control and cost reduction

(14) Co-ordination and co-operation with the other departments

(15) Research and developments in materials management and their use

*Check Your Progress*

iv. What are the three types of inventories?

v. What is MRP?

## CASE STUDY

Rajeev Sehgal is a middle level sales and service manager in a company engaged in electrical equipments' etc. He is accountable for hiring, training and managing his departmental staff, the day-to-day operations, planning for targets on weekly as well as monthly basis and dealing with the critical situations such as breakdown, non-delivery, etc., which keep happening all the time.

Yesterday, he attended a conference on marketing and spent about three hours meeting delegates all over. He picked up some leads too, which he intended to

follow-up once he reached office. Today morning he reached office at 9.30 a.m. and realised that he has called a group of four sales executive, who joined last week for briefing, at 9.30 a.m. As he reached his cabin, his secretary greeted him and then proceeded to tell him, "Shah and Sons people wanted to talk to you since yesterday about deliveries of their order. The marketing director, Mr John, has called a meeting today. The production engineer, Ramesh, had come to discuss about the delay in work yesterday. The four new people are waiting outside", she said in a row, handing over the letters, he had wanted to see yesterday.

"Reena, send these executives and please send a cup of coffee also." Rajeev spent next few minutes talking to the new executives. He finalized their training sessions and fixed up things with training manager and his direct assistant, the assistant sales manager for training schedules. Once they left Reena came again with his mail, which had letters, enquiries and reports. She reminded him of the meeting and the problem with Shah and Sons.

He started to speak on the phone with Neeraj Shah, one of the partner and Neeraj said, "Our entire schedule is upset because your people didn't give the material yesterday. Now I will have to reschedule everything. Since yesterday, customers are calling me constantly and I have no answer for them." He then called Ramesh and discussed the delay in delivery, "Ramesh, I want this order out by 1. O' clock whatever happens/" Ramesh told him that only an hour's job was left.

Rajeev proceeded for the meeting and found six members of the committee waiting in marketing director's cabin for him. The meeting started with setting of targets for the next month, the performance of the teams and other issues. It was over by 1 p.m. and Rajeev immediately rushed to check up the delivery status. To his relief, the material was delivered on time.

## THE TASKS OF A PROFESSIONAL MANAGER

He reached his cabin and looked at his appointments. He had to meet the general manager of Sudarshan Furnaces, a new business he was trying to develop.

Around 2. p.m. he called Reena and asked if there was anything of importance. "Seema won't be coming for the next whole week. Her calls need to be handed over to someone else. We had to finalize the weekly targets by today evening", replied Reena.

Rajeev came back at 3 p.m. after meeting the GM of Sudarshan Furnaces and thought that they might give him some business by next month. The GM had found the products quite suitable for their work. Reena told him, "The executives are coming at 4 p.m. for performance review meeting you had finalised last week". Rajeev spent the next half an hour at their reports, targets and revenue status. The performance review meeting got over at 5 O' clock. Rajeev suddenly felt very tired. He just sat for some time and thought "What have I achieved today - some trouble-shooting, finding ways out of crisis, meetings - is all I did most of the day. I have so little time for planning or evaluating what's been done. These days, all my time I spend trying to chase different production targets so that my existing clients are satisfied. The kind of planning or objective-oriented work, I want to do always takes a back seat. Rest of the time I am sitting in meetings and listening to all the details about others' plans and targets. I wonder why am I not able to do this myself"

### Review Questions

1. What are the demands of Rajeev's job? What are the constraints in his job?

2. What kind of interpersonal role is Rajeev playing?
3. "The manager must have a proactive role in the organisation'. In this context analyse the working style of Rajeev in the case.

NOTES

ILLUSTRATED CASE ANALYSIS

The case illustrates the multiple job responsibilities, constraints and expectations from a typical manager's role in most of the organisations. The basic model of management defines functions of management as planning, organising, directing and control. However, it is unlikely that role of a manager would be limited to these four only. At different levels, managerial responsibilities keep changing and at times, their proportion is different in a mixed role.

## 3.11 SUMMARY

Materials management concept is to manage resources in an integrative way for national economic development. This is possible with the development Management Information System

(MIS), technological innovations and selection of economic and newly-developed materials for manufacture. It is the management's responsibility to develop the materials management system, which will find the ways and means for most efficient and most effective use of its resources using new technological processes, methods and ideas. The various resources to be fully utilized are men, money and materials and therefore there is importance of materials management. This will be further clear from the examples given below in the table about the expenditure incurred in the materials resource.

Materials worth Rupees 30,000 crores flow in various production channel annually in India, out of which about Rupees 15,000 crores are held up in the stock and out of which Rupees 1200 crores worth materials are inactive, obsolete and scrap.

## ANSWERS TO 'CHECK YOUR PROGRESS'

(i) Materials Management is simply the process by which an organization is supplied with the goods and services that it needs to achieve its objectives of buying, storage and movement of materials.

(Ii) The various types of materials to be managed are:

(a) Purchased materials

(b) Work in process (WIP) materials

(c) Finished goods

(iii) Ordering: Costs such as tendering, stationary, postage, receiving, inspection and bill payment, staff and the delivery that incurred while purchasing material.

(iv) There are three types of inventories.

(i) Raw materials

(ii) Purchased goods

(iii) Finished parts and components

(v) The MRP is a technique used to plan the materials starting from the raw materials, finished parts, components, sub-assemblies and assemblies as per

Bill of Materials (BOM) to procure or produce them to support a Master Production Schedule (MPS).

## 3.12 TEST YOURSELF

NOTES

1) What do you mean by the term 'Material'?
2) Explain organization structure of Materials Management Department.
3) Describe functions of Materials Management.
4) Explain integrated concept of Materials Management.
5) What are the advantages in integrated materials management concept?
6) What are the objectives and advantages of Materials Management?
7) Explain the various functions of Materials Management.

## 3.13 REFERENCES


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## 3.14 FURTHER READING


- *Production and Operations Management by S. Anil Kumar and N. Suresh*
- *Production and Operations Management by S.N. Chary*
- *Operations Management by Jae K. Shim, Joel G. Siegel*

# BLOCK II

# 4 PURCHASING

NOTES

***The Chapter Covers :***



***Learning Objectives:***

After going through this chapter, you should be able to

- Explain Objectives and Parameters of Purchasing
- Explain Purchasing Parameters
- Make selection of suppliers
- Understand Purchasing System
- Recognize criteria for evaluation

## 4.1 INTRODUCTION

Purchasing is an important function of materials management. In any industry purchase means buying of equipments, materials, tools, parts etc. required for industry. The importance of the purchase function varies with nature and size of industry. In small industry, this function is performed by works manager and in large manufacturing concern; this function is done by a separate department. The moment a buyer places an order he commits a substantial portion of the finance of the corporation which affects the working capital and cash flow position. He is a highly responsible person who meets various salesmen and thus can be considered to have been contributing to the public relations efforts of the company. Thus, the buyer can make or mar the company's image by his excellent or poor relations with the vendors.

According to Alford and Beaty, "Purchasing is the procuring of materials, supplies, machine tools and services required for the equipment, maintenance and operation of the manufacturing plant."

## 4.2 OBJECTIVES OF PURCHASING:

The basic objective of the purchasing function is to ensure continuity of supply of raw materials, sub-contracted items and spare parts and to reduce the ultimate cost of the finished goods. In other words, the objective is not only to procure the raw materials at the lowest price but to reduce the cost of the final product.

The objectives of the purchasing department can be outlined as under:

1) **To avail the materials, suppliers and equipments at the minimum possible costs:** These are the inputs in the manufacturing operations. The minimization of the input cost increases the productivity and resultantly the profitability of the operations.

2) **To ensure the continuous flow of production** through continuous supply of raw materials, components, tools etc. with repair and maintenance service.

3) **To increase the asset turnover:** The investment in the inventories should be kept minimum in relation to the volume of sales. This will increase the turnover of the assets and thus the profitability of the company.

4) **To develop an alternative source of supply:** Exploration of alternative sources of supply of materials increases the bargaining ability of the buyer, minimization of cost of materials and increases the ability to meet the emergencies.

5) **To establish and maintain the good relations with the suppliers:** Maintenance of good relations with the supplier helps in evolving a favorable image in the business circles. Such relations are beneficial to the buyer in terms of changing the reasonable price, preferential allocation of material in case of material shortages, etc.

6) **To achieve maximum integration with other department of the company:** The purchase function is related with production department for specifications and flow of material, engineering department for the purchase of tools, equipments and machines, marketing department for the forecasts of sales and its impact on procurement of materials, financial department for the purpose of maintaining levels of materials and estimating the working capital required, personnel department for the purpose of manning and developing the personnel of purchase department and maintaining good vendor relationship.

7) To train and develop the personnel: Purchasing department is manned with varied types of personnel. The company should try to build the imaginative employee force through training and development.

8) Efficient record keeping and management reporting: Paper processing is inherent in the purchase function. Such paper processing should be standardized so that record keeping can be facilitated. Periodic reporting to the management about the purchase activities justifies the independent existence of the department.

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## 4.3 FUNCTIONS OF PURCHASING DEPARTMENT:

The main functions of the Purchase Department are defined as follows:

1) Procurement of stores through indigenous and foreign sources as required in accordance with the rules in force.

2) Checking of requisitions/purchase indents.

3) Selection of suppliers for issue of enquiries.

4) Issuing enquiries/tenders and obtaining quotations.

5) Analyzing quotations and bids etc., and preparation of comparative statement (quotation charts).

6) Consultation with the Indenter for selection and approval of quotations and with Accounts Officer for pre-audit.

7) Negotiating contracts.

8) Checking legal conditions of contracts.

9) Consulting Administrative Officer or Secretary, NCSM - where necessary.

10) Issue of Purchase Orders.

11) Follow-up of purchase orders for delivery in due time

12) Verification and passing of suppliers' bills to see that payments are made promptly.

13) Correspondence and dealing with suppliers, carriers etc., regarding shortages, rejections etc., reported by the Stores Department.

14) Maintenance of purchase records.

15) Maintenance of progressive expenditure statement, sub-head wise.

16) Maintenance of vendor performance records/data.

17) Arrangement for Insurance Surveys, as and when necessary.

18) Clearance of foreign consignments.

19) Keeping various Departments/Divisions informed of the progress of their indents in case of delay in obtaining supplies.

20) Serving as an information center on the materials' knowledge i.e. their prices, source of supply, specification and other allied matters.

21) Development of reliable and alternate sources of supply.

## 4.4 PARAMETERS OF PURCHASING:

The success of any manufacturing activity is largely dependent on the procurement of raw materials of right quality, in the right quantities, from right source, at the right time and at right price popularly known as ten 'R's' of the art of efficient purchasing. They are described as the basic principles of purchasing. There are other well known parameters such as right contractual terms, right material, right place, right mode of transportation and right attitude are also considered for purchasing.

1) **Right price:** It is the primary concern of any manufacturing organization to get an item at the right price. But right price need not be the lowest price. It is very difficult to determine the right price; general guidance can be had from the cost structure of the product. The 'tender system' of buying is normally used in public sector organizations but the objective should be to identify the lowest 'responsible' bidder and not the lowest bidder. The technique of 'learning curve' also helps the purchase agent to determine the price of items with high labour content. The price can be kept low by proper planning and not by rush buying. Price negotiation also helps to determine the right prices.

2) **Right quality:** Right quality implies that quality should be available, measurable and understandable as far as practicable. In order to determine the quality of a product sampling schemes will be useful. The right quality is determined by the cost of materials and the technical characteristics as suited to the specific requirements. The quality particulars are normally obtained from the indents. Since the objective of purchasing is to ensure continuity of supply to the user departments, the time at which the material is provided to the user department assumes great importance.

3) **Right time:** For determining the right time, the purchase manager should have lead time information for all products and analyze its components for reducing the same. Lead time is the total time elapsed between the recognition of the need of an item till the item arrives and is provided for use. This covers the entire duration of the materials cycle and consists of pre-contractual administrative lead time, manufacturing and transporting lead time and inspection lead time. Since the inventory increases with higher lead time, it is desirable to analyze each component of the lead time so as to reduce the first and third components which are controllable. While determining the purchases, the buyer has to consider emergency situations like floods, strikes, etc. He should have 'contingency plans' when force major clauses become operative, for instance, the material is not available due to strike, lock-out, floods, and earthquakes.

4) **Right source:** The source from which the material is procured should be dependable and capable of supplying items of uniform quality. The buyer has to decide which item should be directly obtained from the manufacturer. Source selection, source development and vendor rating play an important role in buyer-seller relationships. In emergencies, open market purchases and bazaar purchases are restored to.

5) **Right quantity:** The right quantity is the most important parameter in buying. Concepts, such as, economic order quantity, economic purchase quantity, fixed period and fixed quantity systems, will serve as broad guidelines. But the buyer has to use his knowledge, experience and common sense to determine the quantity after considering factors such as price structure, discounts, availability of the item, favorable reciprocal relations, and make or buy consideration.

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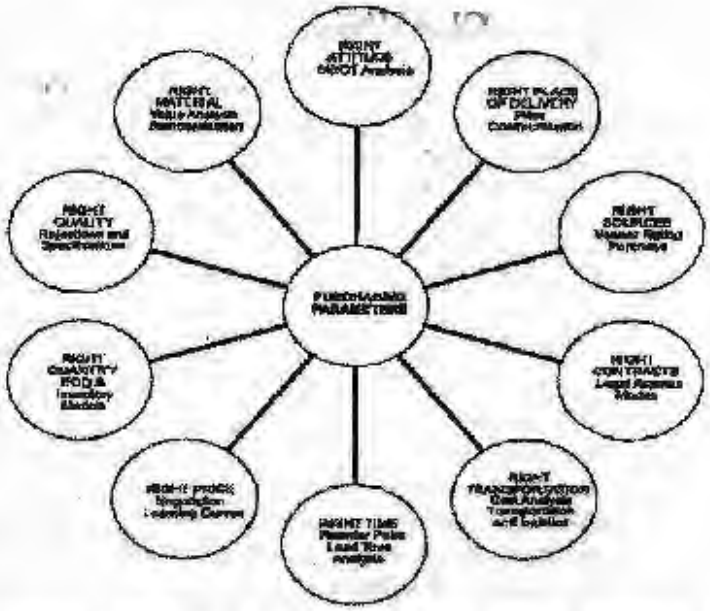


6) **Right attitude:** Developing the right attitude, too, is necessary as one often comes across such statement: 'Purchasing knows the price of everything and value of nothing'; 'we buy price and not cost'; 'when will our order placers become purchase managers?'; 'Purchasing acts like a post box'. Therefore, purchasing should keep 'progress' as its key activity and should be future-oriented. The purchase manager should be innovative and his long-term objective should be to minimize the cost of the ultimate product. He will be able to achieve this if he aims himself with techniques, such as, value analysis, materials intelligence, purchases research, SWOT analysis, purchase budget lead time analysis, etc.

7) **Right contracts:** The buyer has to adopt separate policies and procedures for capital and consumer items. He should be able to distinguish between indigenous and international purchasing procedures. He should be aware of the legal and contractual aspects in international practices.

8) **Right material:** Right type of material required for the production is an important parameter in purchasing. Techniques, such as, value analysis will enable the buyer to locate the right material.

9) **Right transportation:** Right mode of transportation has to be identified as this forms a critical segment in the cost profile of an item. It is an established fact that the cost of the shipping of ore, gravel, sand, etc., is normally more than the cost of the item itself.

10) **Right place of delivery:** Specifying the right place of delivery, like head office or works, would often minimize the handling and transportation cost.

## 4.5 PURCHASING PROCEDURE:

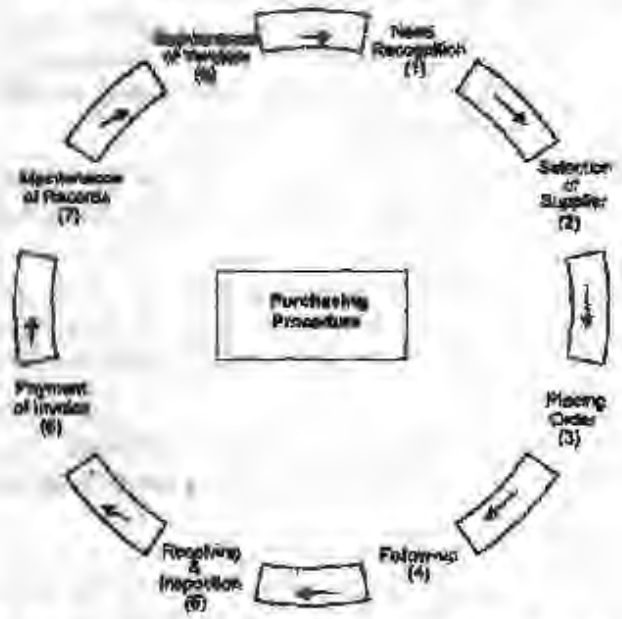
The procedure describes the sequence of steps leading to the completion of an identified specific task. The purchasing procedure comprises the following steps as indicated in figure.

1) **Recognition of the need:** The initiation of procedure starts with the recognition of the need by the needy section. The demand is lodged with the purchase department in the prescribed Purchase Requisition Form forwarded by the authorized person either directly or through the Stores Department. The purchase requisition clearly specifies the details, such as, specification of materials, quality and quantity, suggested supplier, etc. Generally, the low value sundries and items of common use are purchased for stock while costlier and special items are

purchased according the production programmes. Generally, the corporate level executives are authorized signatories to such demands. Such purchases are approved by the Board of Directors. The reference of the approval is made on requisition and a copy of the requisition is sent to the secretary for the purpose of overall planning and budgeting.

2) **The selection of the supplier:** The process of selection of supplier involves two basic aspects: searching for all possible sources and short listing out of the identified sources. The complete information about the supplier is available from various sources, such as, trade directories, advertisement in trade journals, direct mailing by the suppliers, interview with suppliers, salesmen, suggestions from business associates, visit to trade fair, participation in industries convention, etc. Identification of more and more sources helps in selecting better and economical supplier. It should be noted that the low bidder is not always the best bidder. When everything except price is equal, the low bidder will be selected. The important considerations in the selection are the price, ability to supply the required quantity, maintenance of quality standards, financial standing etc. It should be noted that it is not necessary to go for this process for all types of purchases. For the repetitive orders and for the purchases of low-value, small lot items, generally the previous suppliers with good records are preferred.

3) **Placing the order:** Once the supplier is selected the next step is to place the purchase order. Purchase order is a letter sent to the supplier asking to supply the said material. At least six copies of purchase order are prepared by the purchase section and each copy is separately signed by the purchase officer. Out these copies, one copy each is sent to store-keeper, supplier, accounts section, inspection department and to the department placing the requisition and one copy is retained by the purchase department for record.




4) **Follow-up of the order:** Follow-up procedure should be employed wherever the costs and risks resulting from the delayed deliveries of materials are greater than the cost of follow-up procedure, the follow-up procedure tries to see that the purchase order is confirmed by the supplier and the delivery is promised. It is also necessary to review the outstanding orders at regular intervals and to communicate with the supplier in case of need. Generally, a routine urge is made to the supplier by sending a printed post card or a circular letter asking him to confirm that the delivery is on the way or will be made as per agreement. In

absence of any reply or unsatisfactory reply, the supplier may be contact through personal letter, phone, telegram and/or even personal visit.

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5) **Receiving and inspection of the materials:** The receiving department receives the materials supplied by the vendor. The quantity are verified and tallied with the purchase order. The receipt of the materials is recorded on the specially designed receiving slips or forms which also specify the name of the vendor and the purchase order number. It also records any discrepancy, damaged condition of the consignment or inferiority of the materials. The purchase department is informed immediately about the receipt of the materials. Usually a copy of the receiving slip is sent to the purchase department.

6) **Payment of the invoice:** When the goods are received in satisfactory condition, the invoice is checked before it is approved for the payment. The invoice is checked to see that the goods were duly authorized to purchase, they were properly ordered, they are priced as per the agreed terms, the quantity and quality confirm to the order, the calculations are arithmetically correct etc.

7) **Maintenance of the records:** Maintenance of the records is an important part and parcel of the efficient purchase function. In the industrial firms, most of the purchases are repeat orders and hence the past records serve as a good guide for the future action. They are very useful for deciding the timings of the purchases and in selecting the best source of the supply.

8) **Maintenance of vendor relations:** The quantum and frequency of the transactions with the same key suppliers provide a platform for the purchase department to establish and maintain good relations with them. Good relations develop mutual trust and confidence in the course of the time which is beneficial to both the parties. The efficiency of the purchase department can be measured by the amount of the goodwill it has with its suppliers.

## 4.6 SELECTION OF SUPPLIERS

Selection of the right supplier is the responsibility of the purchase department. It can contribute substantially to the fundamental objectives of the business enterprise. Different strategies are required for acquiring different types of materials. The selection of supplier for standardized products will differ from non-standardized products. Following factors are considered for the selection of suppliers:

### A. SOURCES OF SUPPLIER

The best buying is possible only when the decision maker is familiar with all possible sources of supply and their respective terms and conditions. The purchase department should try to locate the appropriate sources of the supplier of various types of materials. This is known as 'survey stage'. A survey of the following will help in developing the possible sources of supply:

1) Specialized trade directories.
2) Assistance of professional bodies or consultants.
3) The buyer's guide or purchase handbook.
4) The manufacturer's or distributor's catalogue.
5) Advertisements in dailies.
6) Advertisement in specialized trade journals.
7) Trade fair exhibitions.

*Check Your Progress*

1) What is purchasing?
2) What do you mean by ten R's of purchasing?

### B. DEVELOPMENT OF APPROVED LIST OF SUPPLIERS

The survey stage highlights the existence of the source. A business inquiry is made with the appropriate supplier. It is known as 'Inquiry Stage'. Here a short listing is made out of the given sources of suppliers in terms of production

facilities and capacity, financial standing, product quality, possibility of timely supply, technical competence, manufacturing efficiency, general business policies followed, standing in the industry, competitive attitude, and interest in buying orders etc.

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## C. EVALUATION AND SELECTION OF THE SUPPLIER

The purchase policy and procedure differ according to the type of items to be purchased. Hence, evolution and selection of the supplier differ accordingly. The following variables to be considered while evaluating the quotations of the suppliers:

1) **Cost Factors:** Price, transportation cost, installation cost if any, tooling and other operations cost, incidence of sales tax and excise duty, terms of payment and cash discount are considered in cost factor.

2) **Delivery:** Routing and F.O.B. terms are important in determining the point at which the title to the goods passes from vendor to the buyer and the responsibility for the payment of the payment charges.

3) **Design and Specification Factors:** Specification compliance, specification deviations, specification advantages, important dimensions and weights are considered in line with the demonstration of sample, experience of other users, after sale services etc.

4) **Legal Factors:** Legal factors include warranty, cancellation provision, patent protection, public liability, federal laws and reputation compliance.

5) **Vendor Rating:** The evaluation of supplier or vendor rating provides valuable information which help in improving the quality of the decision. In the vendor rating three basic aspects are considered namely quality, service and price. How much weight should be given to each of these factors is a matter of judgment and is decided according to the specific need of the organization. Quality would be the main consideration in the manufacturing of the electrical equipments while price would be the prime consideration in the product having a tense competitive market and for a company procuring its requirements under the blanket contract with agreed price, the supplier rating would be done on the basis of two variables namely quality and delivery.

The Development Project Committee of the National Association of Purchasing Agents (U.S.A.) has suggested following methods for evaluating the performance of past suppliers.

1) **The categorical plan:** Under this method the members of the buying staff related with the supplier like receiving section, quality control department, manufacturing department etc., are required to assess the performance of each supplier. The rating sheets are provided with the record of the supplier, their product and the list of factors for the evaluation purposes. The members of the buying staff are required to assign the plus or minus notations against each factor. The periodic meetings, usually at the interval of one month, are held by senior man of the buying staff to consider the individual rating of each section. The consolidation of the individual rating is done on the basis of the net plus value and accordingly, the suppliers are assigned the categories such as 'preferred', 'neutral' or 'unsatisfactory'. Such ratings are used for the future guidance. This is a very simple and inexpensive method. However, it is not precise. Its quality heavily depends on the experience and ability of the buyer to judge the situation. As compared to other methods, the degree of subjective judgment is very high as rating is based on personal whim and the vague impressions of the buyer. As the

quantitative data supported by the profits do not exist, it is not possible to institute any corrective action with the vendor. The rating is done on the basis of memory, and thus it becomes only a routine exercise without any critical analysis.

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2) **The weighted-point method:** The weighted-point method provides the quantitative data for each factor of evaluation. The weights are assigned to each factor of evaluation according to the need of the organization, e.g., a company decides the three factors to be considered- quality, price and timely delivery. It assigns the relative weight to each of these factors as under:

Quality ..... 50 points

Price ..... 30 points

Timely delivery ..... 20 points

The evaluation of each supplier is made in accordance with the aforesaid factors and weights and the composite weighted-points are ascertained for each suppliers-A, B and C- are rated under this method. First of all the specific rating under each factor will be made and then the consolidation of all the factors will be made for the purpose of judgment.

3) **Quality rating:** Percentage of quantity accepted among the total quantity is called quality rating. In other words, the quality of the materials is judged on the basis of the degree of acceptance and rejections. For the purpose of comparison, the percentage degree of acceptance will be calculated in relation to the total lots received. Price rating is done on the basis of net price charged by the supplier. Timely delivery rating will be done comparing with the average delivery schedule of the supplier.

4) **The cost-ratio plan:** Under this method, the vendor rating is done on the basis of various costs incurred for procuring the materials from various suppliers. The cost-ratios are ascertained delivery etc. The cost-ratios are ascertained for the different rating variables such as quality, price, timely delivery etc. The cost-ratio is calculated in percentage on the basis of total individual cost and total value of purchases. At the end, all such cost-ratios will be adjusted with the quoted price per unit. The plus cost-ratio will increase the unit price while the minus cost-ratio will decrease the unit price. The net adjusted unit price will indicate the vendor rating. The vendor with the lowest net adjusted unit price will be the best supplier and so on. Certain quality costs can be inspection cost, cost of defectives, reworking costs and manufacturing losses on rejected items etc. Certain delivery costs can be postage and telegrams, telephones and extra cost for quick delivery etc.

## 4.7 SPECIAL PURCHASING SYSTEMS

The following are some of the important purchasing systems:

**FORWARD BUYING:**

Forward buying or committing an organization far into the future, usually for a year. Depending upon the availability of the item, the financial policies, the economic order quantity, the quantitative discounts, and the staggered delivery, the future commitment is decided. This type of forward buying is different from speculative buying where the motive is to make capital out of the price changes, by selling the purchased items. Manufacturing organizations normally do not indulge in such buying. However, a few organizations do 'Hedge', particularly in the commodity market by selling or buying contracts.

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**TENDER BUYING:**

In public, all semblance of favoritism, personal preferences should be avoided. As such, it is common for government departments and public sector undertakings to purchase through tenders. Private sector organizations adopt tender buying if the value of purchases is more than the prescribed limits as Rs. 50000 or Rs. 100000. The steps involved are to establish a bidders' list, solicit bids by comparing quotations and place the order with the lowest bidder. However, care has to be taken that the lowest bidder is responsible party and is capable of meeting the delivery schedule and quality requirements. Open tender system or advertisement in newspapers is common in public sector organizations. As advertising bids is costly and time consuming, most private sector organizations solicit tenders only from the renowned suppliers capable of supplying the materials.

**BLANKET ORDER SYSTEM:**

This system minimizes the administrative expenses and is useful for 'C' type items. It is an agreement to provide a required quantity of specified items, over a period of time, usually for one year, at an agreed price. Deliveries are made depending upon the buyer's needs. The system relieves the buyers from routine work, giving him more time for focusing attention on high value items. It requires fewer purchase orders and thus reduces clerical work. It often achieves lower prices through quantity discounts by grouping the requirements. The supplier, under the system maintains adequate inventory to meet the blanket orders.

**ZERO STOCK:**

Some firms try to operate on the basis of zero stock and the supplier holds the stock for these firms. Usually, the firms of the buyer and seller are close to each other so that the raw materials of one are the finished products of another. Alternatively, the system could work well if the seller holds the inventory and if the two parties work in close coordination. However, the price per item in this system will be slightly higher as the supplier will include the inventory carrying cost in the price. In this system, the buyer need not lock up the capital and so the purchasing routine is reduced. This is also significantly reduces obsolescence of inventory, lead time and clerical efforts in paper work. Thus, the seller can devote his marketing efforts to other customers and production scheduling becomes easy.

**RATE CONTRACT:**

The system of rate contract is prevalent in public sector organizations and government departments. It is common for the suppliers to advertise that they are on 'rate contract' for the specific period. After negotiations, the seller and the buyer agree to the rates of items. Application of rate contract has helped many organizations to cut down the internal administrative lead time as individual firms need to go through the central purchasing departments and can place orders directly with the suppliers. However, suppliers always demand higher prices for prompt delivery, as rate difficulty has been avoided by ensuring the delivery of a minimum quantity at the agreed rates. This procedure of fixing a minimum quantity is called the running contract and is being practiced by the railways. The buyer also has an option of increasing the quantity by 25% more than the agreed quantity under this procedure.

**RECIPROCITY:**

Reciprocal buying means purchasing from one's customers in preference to others. It is based on the principle "if you kill my cat, I will kill your dog", and "Do unto your customers as you would have them do unto you". Other things, like soundness from the ethics and economics point of view being equal, the principles of reciprocity can be practiced. However, a purchasing executive should not indulge in reciprocity on his initiative when the terms and conditions are not equal with other suppliers.

It is often sound those less efficient manufacturers and distributors gain by reciprocity what they are unable to gain by price and quality. Since this tends to discourage competition and might lead to higher process and fewer suppliers, reciprocity should be practiced on a selective basis.

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SYSTEMS CONTRACT:

This is a procedure intender to help the buyer and the sellers to reduce administrative expenses and at the same time ensure suitable controls. In this system, the original indent, duly approved by competent authorities, is shipped back with the items and avoids the usual documents like purchase orders, materials requisitions, expediting letters and acknowledgements, delivery period price and invoicing procedure. Carborandum company in the US claims drastic reduction in inventory and elimination of 40000 purchase orders by adopting the system contracting procedure. It is suitable for low unit price items with high consumption.

## 4.8 PURCHASING ORGANIZATION

From the Materials Management and Purchasing view, the purchasing organization is responsible for all purchasing activities (including the processing of requests for quotations and purchase orders).

The purchasing organization is integrated within the organizational structure as follows:

- A purchasing organization can be assigned to several company codes. (= Corporate-group-wide purchasing).
- A purchasing organization can be assigned to one company code. (= Company-specific purchasing).
- A purchasing organization can also exist without being assigned to a company code.
    - o Since each plant must be assigned to a company code, the latter can be determined via the plant at the time of each procurement transaction even if the procuring purchasing organization has not been assigned to a company code.
- A purchasing organization must be assigned to one or more plants. (= Plant-specific purchasing).
- A purchasing organization can be linked to one or more other purchasing organizations. (= reference purchasing organization)
- A purchasing organization can be divided into several purchasing groups that are responsible for different operational areas.
- Each purchasing organization has its own info records and conditions for pricing.
- Each purchasing organization has its own vendor master data.
- Each purchasing organization evaluates its own vendors using MM Vendor Evaluation.
- Authorizations for processing purchasing transactions can be assigned to each purchasing organization.
- All items of an external purchasing document, that is, request for quotation, purchase order, contract, or scheduling agreement, belong to a purchasing organization.
- The purchasing organization is the highest level of aggregation (after the organizational unit "client") for purchasing statistics.

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- The purchasing organization serves as the selection criterion for of one plant.

All of these forms can co-exist within a single client.

**Corporate-group-wide purchasing**

A purchasing organization is responsible for the purchasing activities of different company codes. In this case, you do not assign a company code to the purchasing organization, but specify the company code concerned for each individual purchasing transaction. You assign plants from different company codes to the purchasing organization.

**Company-specific purchasing**

A purchasing organization is responsible for the purchasing activities of just one company code. In this case, you assign a company code to the purchasing organization. The purchasing organization may procure only for this company code. You assign only plants of the company code concerned to the purchasing organization.

**Plant-specific purchasing**

A purchasing organization is responsible for the purchasing activities of one plant. In this case, you assign the plant and the company code of the plant to the purchasing organization. The purchasing organization may procure for this plant only.

**Reference Purchase Organization**

If you wish to work with a mixture of the above organizational forms, the reference purchasing organization is of significance to you. It is possible to allow one purchasing organization to access the contracts and conditions of another - a so-called reference purchasing organization. This makes it possible for advantageous terms negotiated by one purchasing organization to also be used by other purchasing organizations.

**Standard purchasing organization:**

"If several purchasing organizations procure for a certain plant, you can define one of them as the standard purchasing organization for the transactions "pipeline procurement", "consignment" and "stock transfers"." (Matthew, First Post).

"In source determination for stock transfers and consignment, the system automatically utilizes this standard purchasing organization. In the case of goods issues of pipeline materials, the purchasing info records of the standard purchasing organization are read."

**Vendor Rating**

Vendor rating is the result of a formal vendor evaluation system. Vendors or suppliers are given standing, status, or title according to their attainment of some level of performance, such as delivery, lead time, quality, price, or some combination of variables. The motivation for the establishment of such a rating system is part of the effort of manufacturers and service firms to ensure that the desired characteristics of a purchased product or service is built in and not determined later by some after-the-fact indicator. The vendor rating may take the form of a hierarchical ranking from poor to excellent and whatever rankings the firm chooses to insert in between the two. For some firms, the vendor rating may come in the form of some sort of award system or as some variation of certification. Much of this attention to vender rating is a direct result of the widespread implementation of the just-in-time concept in the United States and its focus on the critical role of the buyer-supplier relationship.

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Most firms want vendors that will produce all of the products and services defect-free and deliver them just in time (or as close to this ideal as reasonably possible). Some type of vehicle is needed to determine which supplying firms are capable of coming satisfactorily close to this and thus to be retained as current suppliers. One such vehicle is the vendor rating.

In order to accomplish the rating of vendors, some sort of review process must take place. The process begins with the identification of vendors who not only can supply the needed product or service but is a strategic match for the buying firm. Then important factors to be used as criteria for vendor evaluation are determined. These are usually variables that add value to the process through increased service or decreased cost. After determining which factors are critical, a method is devised that allows the vendor to be judged or rated on each individual factor.

It could be numeric rating or a Likert-scale ranking. The individual ratings can then be weighted according to importance, and pooled to arrive at an overall vendor rating. The process can be somewhat complex in that many factors can be complementary or conflicting. The process is further complicated by fact that some factors are quantitatively measured and others subjectively.

Once established, the rating system must be introduced to the supplying firm through some sort of formal education process. Once the buying firm is assured that the vendor understands what is expected and is able and willing to participate, the evaluation process can begin. The evaluation could be an ongoing process or it could occur within a predetermined time frame, such as quarterly. Of course the rating must be conveyed to the participating vendor with some firms actually publishing overall vendor standings. If problems are exposed, the vendor should formally present an action plan designed to overcome any problems that may have surfaced. Many buying firms require the vendor to show continuing improvement in predetermined critical areas.

## 4.9 CRITERIA FOR EVALUATION

Vendor performance is usually evaluated in the areas of pricing, quality, delivery, and service. Each area has a number of factors that some firms deem critical to successful vendor performance.

Pricing factors include the following:

- **Competitive pricing:** The prices paid should be comparable to those of vendors providing similar product and services. Quote requests should compare favorably to other vendors.
- **Price stability:** Prices should be reasonably stable over time.
- **Price accuracy:** There should be a low number of variances from purchase-order prices on invoiced received.
- **Advance notice of price changes:** The vendor should provide adequate advance notice of price changes.
- **Sensitive to costs:** The vendor should demonstrate respect for the customer firm's bottom line and show an understanding of its needs. Possible cost savings could be suggested. The vendor should also exhibit knowledge of the market and share this insight with the buying firm.
- **Billing:** Are vendor invoices are accurate? The average length of time to receive credit memos should be reasonable. Estimates should not vary significantly from the final invoice. Effective vendor bills are timely and easy to read and understand.

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## Quality factors include:

- **Compliance with purchase order.** The vendor should comply with terms and conditions as stated in the purchase order. Does the vendor show an understanding of the customer firm's expectations?
- **Conformity to specifications.** The product or service must conform to the specifications identified in the request for proposal and purchase order. Does the product perform as expected?
- **Reliability.** Is the rate of product failure within reasonable limits?
- **Reliability of repairs.** Is all repair and rework acceptable?
- **Durability.** Is the time until replacement is necessary reasonable?
- **Support.** Is quality support available from the vendor? Immediate response to and resolution of the problem is desirable.
- **Warranty.** The length and provisions of warranty protection offered should be reasonable. Are warranty problems resolved in a timely manner?
- **State-of-the-art product/service.** Does the vendor offer products and services that are consistent with the industry state-of-the-art? The vendor should consistently refresh product life by adding enhancements. It should also work with the buying firm in new product development.

Delivery factors include the following:

- **Time.** Does the vendor deliver products and services on time; is the actual receipt date on or close to the promised date? Does the promised date correspond to the vendor's published lead times? Also, are requests for information, proposals, and quotes swiftly answered?
- **Quantity.** Does the vendor deliver the correct items or services in the contracted quantity?
- **Lead time.** Is the average time for delivery comparable to that of other vendors for similar products and services?
- **Packaging.** Packaging should be sturdy, suitable, properly marked, and undamaged. Pallets should be the proper size with no overhang.
- **Documentation.** Does the vendor furnish proper documents (packing slips, invoices, technical manual, etc.) with correct material codes and proper purchase order numbers?
- **Emergency delivery.** Does the vendor demonstrate extra effort to meet requirements when an emergency delivery is requested?

Finally, these are service factors to consider:

- **Good vendor representatives have sincere desire to serve.** Vendor reps display courteous and professional approach, and handle complaints effectively. The vendor should also provide up-to-date catalogs, price information, and technical information. Does the vendor act as the buying firm's advocate within the supplying firm?
- **Inside sales.** Inside sales should display knowledge of buying firms needs. It should also be helpful with customer inquiries involving order confirmation, shipping schedules, shipping discrepancies, and invoice errors.

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- **Technical support.** Does the vendor provide technical support for maintenance, repair, and installation situations? Does it provide technical instructions, documentation, general information? Are support personnel courteous, professional, and knowledgeable? The vendor should provide training on the effective use of its products or services.
- **Emergency support.** Does the vendor provide emergency support for repair or replacement of a failed product?
- **Problem resolution.** The vendor should respond in a timely manner to resolve problems. An excellent vendor provides follow-up on status of problem correction.

A 2011 article in Supply Management notes that while pricing, quality, delivery, and service are suitable for supplies that are not essential to the continued success of the buying firm, a more comprehensive approach is needed for suppliers that are critical to the success of the firm's strategy or competitive advantage. For firms that fall into the latter category performance may need to be measured by the following 7 C's.

1. **Competency** - managerial, technical, administrative, and professional competence of the supplying firm.
2. **Capacity** - supplier's ability to meet physical, intellectual and financial requirements.
3. **Commitment** - supplier's willingness to commit physical, intellectual and financial resources.
4. **Control** - effective management control and information systems.
5. **Cash resources** - financial resources and stability of the supplier. Profit, ROI, ROE, asset-turnover ratio.
6. **Cost** - total acquisition cost, not just price.
7. **Consistency** - supplier's ability to exhibit quality and reliability over time.

If two or more firms supply the same or similar products or services, a standard set of criteria can apply to the vendor's performance evaluation. However, for different types of firms or firms supplying different products or services, standardized evaluation criteria may not be valid. In this case, the buying firm will have to adjust its criteria for the individual vendor. For example, Honda of America adjusts its performance criteria to account for the impact of supplier problems on consumer satisfaction or safety. A supplier of brakes would be held to a stricter standard than a supplier of radio knobs.

## 4.10 AWARDS AND CERTIFICATION

*Check Your Progress*

3) Define Quality rating.
4) Explain purchasing organization.

Many buying firms utilize awards and certification programs to rate vendors. Attainment of certification status or an award serves as an indicator of supplier excellence. Certification and awards-program recognition represents a final step in an intense journey that involves rigorous data collection under the total-quality-management rubric as well as multitudes of meetings with suppliers and purchasing internal customers. Serious buying firms view these programs as an integral part of their overall efforts to improve the total value of the company.

The attainment of a supplier award usually serves as an indication that the vendor has been rated as excellent. Intel awards their best suppliers the Supplier Continuous Quality Improvement Award (SCQI). Other firms may utilize a hierarchy of awards to indicate varying degrees of performance from satisfactory to excellent.

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DaimlerChrysler awards its best suppliers the Gold Pent star Award. Several hundred vending firms receive this award per year. However, only a handful (less than a dozen) of DaimlerChrysler's vendors is good enough to garner the Platinum Pent star Award.

For other firms, supplier certification is desirable. Supplier certification can be defined as a process for ensuring that suppliers maintain specific levels of performance in the areas of price, quality, delivery, and service. Certification implies that participating firms have reached a level of excellence that other firms were unable or unwilling to achieve. For example a quality certified firm maintains a level of quality such that customer-receiving inspection may be utilized with decreasing frequency up to the point where it is eliminated altogether. Theoretically, this will ensure that all of the supplier's products meet the customer's product specifications. In this case, the goal of supplier certification is quality at the source.

While it is uncertain whether individual firms are consistent in the manner in which they certify vendors, a quality certification would likely require that the vending firm be part of a formal education program, utilize statistical process control (SPC), and have a quality assurance plan (set written procedures).

## 4.11 BENEFITS

Benefits of vendor rating systems include:

- Helping minimize subjectivity in judgment and make it possible to consider all relevant criteria in assessing suppliers.
- Providing feedback from all areas in one package.
- Facilitating better communication with vendors.
- Providing overall control of the vendor base.
- Requiring specific action to correct identified performance weaknesses.
- Establishing continuous review standards for vendors, thus ensuring continuous improvement of vendor performance.
- Building vendor partnerships, especially with suppliers having strategic links.
- Developing a performance-based culture.

Vendor ratings systems provide a process for measuring those factors that add value to the buying firm through value addition or decreased cost. The process will continually evolve and the criteria will change to meet current issues and concerns.

For example, some feel that supplier evaluation must now reflect the strategic direction of the buying company's environmental initiatives. As a result, some firms have recently developed supplier evaluation systems that place significant weight on environmental criteria. It would seem that the concept will remain valid for some time.

**CASE STUDY - Hul plans to handle inventory through material management**

The company is also deploying its entire portfolio of brands in the marketplace to regain lost shares, cutting prices and relaunching brands to drive growth rates. "The strategy of 'straddling the pyramid' at a time like this gives us the ability to capture the up trading opportunities while simultaneously insuring us against the inevitable down trading that also occurs in a downturn.

This allows us to retain and strengthen our competitiveness through the power of our portfolio even in uncertain times." he said, He was referring to the inherent competitive advantage that HUL enjoyed through its portfolio of powerful brands, packs and

product formats at varying price points that makes its offerings affordable and accessible to consumers. Hindustan Unilever chairman Harish Manwani said at the company's 76th AGM in Mumbai on Friday.

HUL has rolled out a new go-to-market distribution model. This model reduces complexity at the front-end and enables efficiencies across one extended supply chain and consequently considerable reduction in cost. HUL is pumping in higher investments in advertising and promoting smaller brands, such as Rexona, Breeze or Hamam in soaps.

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It also dropped prices of brands like Wheel or Surf and restored grammage or product quantity across brands, such as Wheel and Lux, to take on the growing competition from more price competitive national and regional brands.

Currently, HUL is implementing risk mitigation strategies such as shorter response and planning cycles to deal with the high volatility in business operations related to input costs, demand trends, commodity prices, inflation and interest rates.

## 4.12 SUMMARY

Purchasing refers to a business or organization attempting for acquiring goods or services to accomplish the goals of the enterprise. Though there are several organizations that attempt to set standards in the purchasing process, processes can vary greatly between organizations. Typically the word "purchasing" is not used interchangeably with the word "procurement", since procurement typically includes Expediting, Supplier Quality, and Traffic and Logistics (T&L) in addition to Purchasing.

Purchasing managers/directors, and procurement managers/directors guide the organization's acquisition procedures and standards. Most organizations use a three-way check as the foundation of their purchasing programs. This involves three departments in the organization completing separate parts of the acquisition process. The three departments do not all report to the same senior manager to prevent unethical practices and lend credibility to the process. These departments can be purchasing, receiving; and accounts payable or engineering, purchasing and accounts payable; or a plant manager, purchasing and accounts payable. Combinations can vary significantly, but a purchasing department and accounts payable are usually two of the three departments involved.

## ANSWERS TO 'CHECK YOUR PROGRESS'

(i) "Purchasing is the procuring of materials, supplies, machine tools and services required for the equipment, maintenance and operation of the manufacturing plant."

(ii) The success of any manufacturing activity is largely dependent on the procurement of raw materials of right quality, in the right quantities, from right source, at the right time and at right price popularly known as ten 'R's' of the art of efficient purchasing.

(iii) Percentage of quantity accepted among the total quantity is called quality rating.

(iv) A purchasing organization is responsible for the purchasing activities of one plant. In this case, you assign the plant and the company code of the plant to the purchasing organization. The purchasing organization may procure for this plant only.

NOTES

## 4.13 TEST YOURSELF

1) Define the term 'Purchasing'. What are the objectives of Purchasing?
2) Explain various functions of Purchasing Department.
3) What are the parameters of Purchasing?
4) Explain the procedure of Purchasing.
5) What are the methods for evaluating the performance of past suppliers?
6) Describe some important purchasing systems.
7) Write a short note on Purchasing Organization.

## 4.14 REFERENCES


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## 4.15 FURTHER READING


- *Production and Operations Management by S. Anil Kumar and N. Suresh*
- *Production and Operations Management by S.N. Chary*
- *Operations Management by Jae K. Shim, Joel G. Siegel*

# 5 CAPACITY PLANNING AND MANUFACTURING RESOURCE PLANNING

*The Chapter Covers :*



*Learning Objectives:*

After going through this chapter, you should be able to

- Explain Manufacturing Resource Planning
- Clarify Just In Time
- Define Process Preparation
- Learn general concepts of MRP
- Explain Enterprise Resource Planning

NOTES

# 5.1 INTRODUCTION

Capacity planning is the process of determining the production capacity needed by an organization to meet changing demands for its products. In the context of capacity planning, "capacity" is the maximum amount of work that an organization is capable of completing in a given period. The phrase is also used in business computing as a synonym for Capacity Management.

A discrepancy between the capacity of an organization and the demands of its customers results in inefficiency, either in under-utilized resources or unfulfilled customers. The goal of capacity planning is to minimize this discrepancy. Demand for an organization's capacity varies based on changes in production output, such as increasing or decreasing the production quantity of an existing product, or producing new products. Better utilization of existing capacity can be accomplished through improvements in overall equipment effectiveness (OEE). Capacity can be increased through introducing new techniques, equipment and materials, increasing the number of workers or machines, increasing the number of shifts, or acquiring additional production facilities.

Capacity is calculated: (number of machines or workers) × (number of shifts) × (utilization) × (efficiency).

The broad classes of capacity planning are lead strategy, lag strategy, and match strategy.

- Lead strategy is adding capacity in anticipation of an increase in demand. Lead strategy is an aggressive strategy with the goal of luring customers away from the company's competitors. The possible disadvantage to this strategy is that it often results in excess inventory, which is costly and often wasteful.
- Lag strategy refers to adding capacity only after the organization is running at full capacity or beyond due to increase in demand. This is a more conservative strategy. It decreases the risk of waste, but it may result in the loss of possible customers.
- Match strategy is adding capacity in small amounts in response to changing demand in the market. This is a more moderate strategy.

In the context of systems engineering, capacity planning is used during system design and system performance monitoring.

Capacity planning is long-term decision that establishes a firms' overall level of resources. It extends over time horizon long enough to obtain resources. Capacity decisions affect the production lead time, customer responsiveness, operating cost and company ability to compete. Inadequate capacity planning can lead to the loss of the customer and business. Excess capacity can drain the company's resources and prevent investments into more lucrative ventures. The question of when capacity should be increased and by how much is the critical decisions.

Capacity - Available or Required?

From a scheduling perspective it is very easy to determine how much capacity (or time) will be required to manufacture a quantity of parts. Simply multiply the Standard Cycle Time by the Number of Parts and divide by the part or process OEE %.

If production is scheduled to produce 500 pieces of product A on a machine having a cycle time of 30 seconds and the OEE for the process is 85%, then the time to produce the parts would be calculated as follows:

(500 Parts X 30 Seconds) / 85% = 17647.1 seconds The OEE index makes it easy to determine whether we have ample capacity to run the required production. In this example 4.2 hours at standard versus 4.9 hours based on the OEE index.

Repeating this process for all the parts that run through a given machine, it is possible to determine the total capacity required to run production.

Capacity Available

If you are considering new work for a piece of equipment or machinery, knowing how much capacity is available to run the work will eventually become part of the overall process. Typically, an annual forecast is used to determine how many hours per year are required. It is also possible that seasonal influences exist within your machine requirements, so perhaps a quarterly or even monthly capacity report is required.

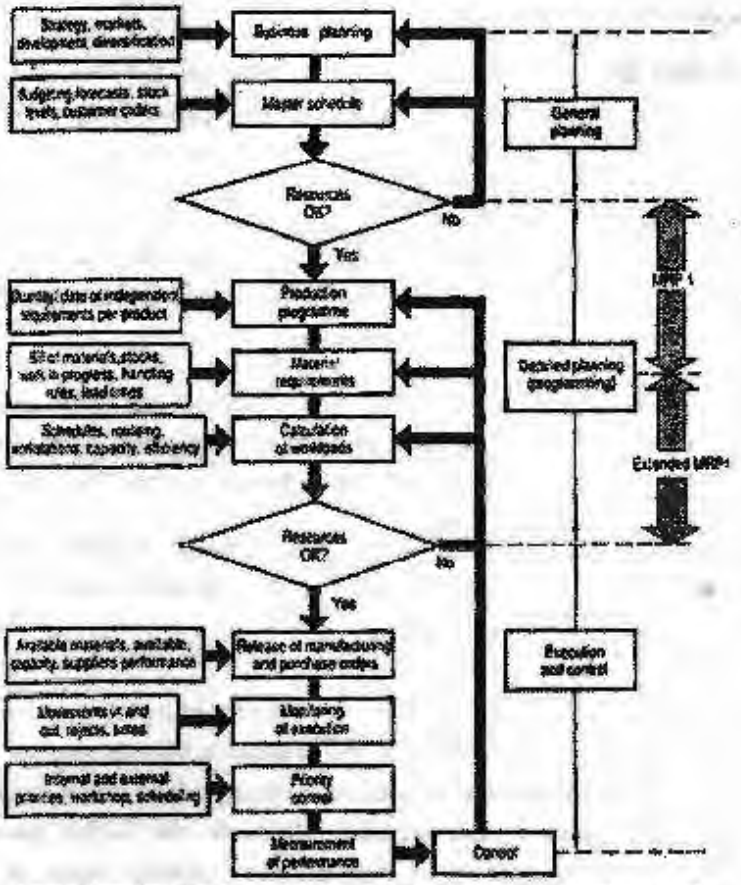
To calculate the total capacity available, we can use the formula from our earlier example and simply adjust or change the volume accordingly based on the period being considered. The available capacity is difference between the required capacity and planned operating capacity.

**Capacity Requirement Planning** (CRP) - It occurs at the level of MRP. It is the process of determining in detail amount of labor and machine resources needed to achieve the required production. - This process considers the lead time of operations and offsets the operations at work center accordingly.

## 5.2 Manufacturing Resource Planning

Manufacturing resource planning (MRP II) is defined by as a method for the effective planning of all resources of a manufacturing company. Ideally, it addresses operational planning in units, financial planning, 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 to data base accuracy, and computer resources. It is a total company management concept for using human resources more productively.




## 5.3 Key functions and features

MRP II is not a proprietary software system and can thus take many forms. It is almost impossible to visualize 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 in an MRP II system are:

- Master production schedule (MPS)
- Item master data (technical data)
- Bill of materials (BOM) (technical data)
- Production resources data (manufacturing technical data)
- Inventories and 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)

together with auxiliary 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.

## 5.4 Industry Specifics

MRP II systems have been implemented in most manufacturing industries. Some industries need specialized functions e.g. lot traceability in regulated manufacturing such as pharmaceuticals or food. Other industries can afford to disregard facilities required by others e.g. the tableware industry has few starting materials - mainly clay - and does not need complex materials planning. Capacity planning is the key to success in this as in many industries, and it is in those that MRP II is less appropriate.

## 5.5 MRP and MRP II - History and Evolution

Material requirements planning (MRP) and manufacturing resource planning (MRPII) are predecessors of enterprise resource planning (ERP), a business information integration system. The development of these manufacturing coordination and integration methods and tools made today's ERP systems possible. Both MRP and MRPII are still widely used, independently and as modules of more comprehensive ERP systems, but the original vision of integrated information systems as we know them today began with the development of MRP and MRPII in manufacturing.

MRP (and MRPII) evolved from the earliest commercial database management package developed by Gene Thomas at IBM in the 1960s. The original structure was called BOMP (bill-of-materials processor), which evolved in the next generation into a more generalized tool called DBOMP (Database Organization and Maintenance Program). These were run on mainframes, such as IBM/360.

The vision for MRP and MRPII was to centralize and integrate business information in a way that would facilitate decision making for production line managers and increase the efficiency of the production line overall. In the 1980s, manufacturers developed systems for calculating the resource requirements of a production run based on sales forecasts. In order to calculate the raw materials needed to produce products and to schedule the purchase of those materials along with the machine and labor time needed, production managers recognized that they would need to use computer and software technology to manage the information. Originally, manufacturing operations built custom software programs that ran on mainframes.

Material requirements planning (MRP) was an early iteration of the integrated information systems vision. MRP information systems helped managers determine the quantity and timing of raw materials purchases. Information systems that would assist managers with other parts of the manufacturing process, MRPII, followed. While MRP was primarily concerned with materials, MRPII was concerned with the integration of all aspects of the manufacturing process, including materials, finance and human relations.

Like today's ERP systems, MRPII was designed to integrate a lot of information by way of a centralized database. However, the hardware, software, and relational database technology of the 1980s was not advanced enough to provide the speed and capacity to run these systems in real-time, and the cost of these systems was prohibitive for most businesses. Nonetheless, the vision had been established, and shifts in the underlying business processes along with rapid advances in technology led to the more affordable enterprise and application integration systems that big businesses and many medium and smaller businesses use today (Monk and Wagner).

## 5.6 MRP and MRP II - General Concepts

Material requirements planning (MRP) and manufacturing resource planning (MRPII) are both incremental information integration business process strategies that are implemented using hardware and modular software applications linked to a central database that stores and delivers business data and information.

MRP is concerned primarily with manufacturing materials while MRPII is concerned with the coordination of the entire manufacturing production, including materials, finance, and human relations. The goal of MRPII is to provide consistent data to all players in the manufacturing process as the product moves through the production line.

Paper-based information systems and non-integrated computer systems that provide paper or disk outputs result in many information errors, including missing data, redundant data, numerical errors that result from being incorrectly keyed into the system, incorrect calculations based on numerical errors, and bad decisions based on incorrect or old data. In addition, some data is unreliable in non-integrated systems because the same data is categorized differently in the individual databases used by different functional areas.

MRPII systems begin with MRP, material requirements planning. MRP allows for the input of sales forecasts from sales and marketing. These forecasts determine the raw materials demand. MRP and MRPII systems draw on a master production

schedule, the breakdown of specific plans for each product on a line. While MRP allows for the coordination of raw materials purchasing, MRPII facilitates the development of a detailed production schedule that accounts for machine and labor capacity, scheduling the production runs according to the arrival of materials. An MRPII output is a final labor and machine schedule. Data about the cost of production, including machine time, labor time and materials used, as well as final production numbers, is provided from the MRPII system to accounting and finance (Monk and Wagner).

## 5.7 Benefits of MRP II

MRP II systems can provide:

- Better control of inventories
- Improved scheduling
- Productive relationships with suppliers

For design / engineering:

- Improved design control
- Better quality and quality control

For financial and costing:

- Reduced working capital for inventory
- Improved cash flow through quicker deliveries
- Accurate inventory records

## 5.8 Enterprise resource planning

Enterprise resource planning (ERP) systems integrate internal and external management information across an entire organization, embracing finance/accounting, manufacturing, sales and service, customer relationship management, etc. ERP systems automate this activity with an integrated software application. Their purpose is to facilitate the flow of information between all business functions inside the boundaries of the organization and manage the connections to outside stakeholders.

ERP systems can run on a variety of computer hardware and network configurations, typically employing a database as a repository for information.

Characteristics

ERP (Enterprise Resource Planning) systems typically include the following characteristics:

- An integrated system that operates in real time (or near to real time), without relying on periodic updates.
- A common database, which supports all applications.
- A consistent look and feel throughout each module.
- Installation of the system without elaborate application/data integration by the Information Technology (IT) department.

Finance/Accounting

General ledger, payables, cash management, fixed assets, receivables, budgeting, consolidation

*Check Your Progress*

1) Define Manufacturing Resource Planning.
2) What is ERP?

NOTES

**Human resources**

Payroll, training, benefits, 401K, recruiting, diversity management

**Manufacturing**

Engineering, bill of materials, work orders, scheduling, capacity, workflow management, quality control, cost management, manufacturing process, manufacturing projects, manufacturing flow, activity based costing, product lifecycle management

**Supply chain management**

Order to cash, inventory, order entry, purchasing, product configuration, supply chain planning, supplier scheduling, inspection of goods, claim processing, commissions

**Project management**

Costing, billing, time and expense, performance units, activity management

**Customer relationship management**

Sales and marketing, commissions, service, customer connect, call center support

**Data services**

Various "self-service" interfaces for customers, suppliers and/or employees

**Access control**

Management of user privileges for various processes

**Origin of "ERP"**

In 1990 Gartner Group first employed the acronym ERP as an extension of material requirements planning (MRP), later manufacturing resource planning and computer-integrated manufacturing. Without supplanting these terms, ERP came to represent a larger whole, reflecting the evolution of application integration beyond manufacturing. Not all ERP packages were developed from a manufacturing core. Vendors variously began with accounting, maintenance and human resources. By the mid-1990s ERP systems addressed all core functions of an enterprise. Beyond corporations, governments and non-profit organizations also began to employ ERP systems.

**Expansion**

ERP systems experienced rapid growth in the 1990s because the year 2000 problem and introduction of the Euro disrupted legacy systems. Many companies took this opportunity to replace such systems with ERP. This rapid growth in sales was followed by a slump in 1999 after these issues had been addressed.

ERP systems initially focused on automating back office functions that did not directly affect customers and the general public. Front office functions such as customer relationship management (CRM) dealt directly with customers, or e-business systems such as e-commerce, e-government, e-telecom, and e-finance, or supplier relationship management (SRM) became integrated later, when the Internet simplified communicating with external parties.

"ERP II" was coined in the early 2000s. It describes web-based software that allows both employees and partners (such as suppliers and customers) real-time access to the systems. "Enterprise application suite" is an alternate name for such systems.

**Components**

- Transactional database

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- Management portal/dashboard
- Business intelligence system
- Customizable reporting
- External access via technology such as web services
- Search
- Document management
- Messaging/chat/wiki
- Workflow management

**Best Practices**

Best practices are incorporated into most ERP systems. This means that the software reflects the vendor's interpretation of the most effective way to perform each business process. Systems vary in the convenience with which the customer can modify these practices. Companies that implemented industry best practices reduced time-consuming project tasks such as configuration, documentation, testing and training. In addition, best practices reduced risk by 71% when compared to other software implementations.

The use of best practices eases compliance with requirements such as IFRS, Sarbanes-Oxley, or Basel II. They can also help comply with de facto industry standards, such as electronic funds transfer. This is because the procedure can be readily codified within the ERP software and replicated with confidence across multiple businesses who share that business requirement.

**Modularity**

Most systems are modular to permit automating some functions but not others. Some common modules, such as finance and accounting, are adopted by nearly all users; others such as human resource management are not. For example, a service company probably has no need for a manufacturing module. Other companies already have a system that they believe to be adequate. Generally speaking, the greater the number of modules selected, the greater the integration benefits, but also the greater the costs, risks and changes involved.

**Connectivity to Plant Floor Information**

ERP systems connect to real-time data and transaction data in a variety of ways. These systems are typically configured by systems integrators, who bring unique knowledge on process, equipment, and vendor solutions.

**Direct integration-** ERP systems have connectivity (communications to plant floor equipment) as part of their product offering. This requires the vendors to offer specific support for the plant floor equipment that their customers operate. ERP vendors must be expert in their own products, and connectivity to other vendor products, including competitors.

**Database integration-** ERP systems connect to plant floor data sources through staging tables in a database. Plant floor systems deposit the necessary information into the database. The ERP system reads the information in the table. The benefit of staging is that ERP vendors do not need to master the complexities of equipment integration. Connectivity becomes the responsibility of the systems integrator.

**Enterprise appliance transaction modules (EATM)-** These devices communicate directly with plant floor equipment and with the ERP system via methods supported

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by the ERP system. EATM can employ a staging table, Web Services, or system-specific program interfaces (APIs). The benefit of an EATM is that it offers an off-the-shelf solution.

Custom-integration solutions - Many system integrators offer custom solutions. These systems tend to have the highest level of initial integration cost, and can have a higher long term maintenance and reliability costs. Long term costs can be minimized through careful system testing and thorough documentation. Custom-integrated solutions typically run on workstation or server class computers.

## 5.9 Implementation

ERP's scope usually implies significant changes to staff work processes and practices. Generally, three types of services are available to help implement such changes-consulting, customization, and support. Implementation time depends on business size, number of modules, customization, the scope of process changes, and the readiness of the customer to take ownership for the project. Modular ERP systems can be implemented in stages. The typical project for a large enterprise consumes about 14 months and requires around 150 consultants. Small projects can require months; multinational and other large implementations can take years. Customization can substantially increase implementation times.

## 5.10 Process preparation

Implementing ERP typically requires changes in existing business processes. Poor understanding of needed process changes prior to starting implementation is a main reason for project failure. It is therefore crucial that organizations thoroughly analyze business processes before implementation. This analysis can identify opportunities for process modernization. It also enables an assessment of the alignment of current processes with those provided by the ERP system. Research indicates that the risk of business process mismatch is decreased by:

- linking current processes to the organization's strategy;
- analyzing the effectiveness of each process;
- Understanding existing automated solutions.

ERP implementation is considerably more difficult (and politically charged) in decentralized organizations, because they often have different processes, business rules, data semantics, authorization hierarchies and decision centers. This may require migrating some business units before others, delaying implementation to work through the necessary changes for each unit, possibly reducing integration (e.g. linking via Master Data management) or customizing the system to meet specific needs.

A potential disadvantage is that adopting "standard" processes can lead to a loss of competitive advantage. While this has happened, losses in one area are often offset by gains in other areas, increasing overall competitive advantage.

### Configuration

Configuring an ERP system is largely a matter of balancing the way the customer wants the system to work with the way it was designed to work. ERP systems typically build many changeable parameters that modify system operation. For example, an organization can select the type of inventory accounting-FIFO or LIFO-to employ, whether to recognize revenue by geographical unit, product line, or distribution channel and whether to pay for shipping costs when a customer returns a purchase.

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### Customization

ERP systems are theoretically based on industry best practices and are intended to be deployed "as is". ERP vendors do offer customers configuration options that allow organizations to incorporate their own business rules but there are often functionality gaps remaining even after the configuration are complete. ERP customers have several options to reconcile functionality gaps, each with their own pros/cons. Technical solutions include rewriting part of the delivered functionality, writing a homegrown bolt-on/add-on module within the ERP system, or interfacing to an external system. All three of these options are varying degrees of system customization, with the first being the most invasive and costly to maintain. Alternatively, there are non-technical options such as changing business practices and/or organizational policies to better match the delivered ERP functionality.

Key differences between customization and configuration include:

- Customization is always optional, whereas the software must always be configured before use (e.g., setting up cost/profit center structures, organizational trees, purchase approval rules, etc.)
- The software was designed to handle various configurations, and behaves predictably in any allowed configuration.
- The effect of configuration changes on system behavior and performance is predictable and is the responsibility of the ERP vendor. The effect of customization is less predictable, is the customer's responsibility and increases testing activities.
- Configuration changes survive upgrades to new software versions. Some customizations (e.g. code that uses pre-defined "hooks" that are called before/after displaying data screens) survive upgrades, though they require retesting. Other customizations (e.g. those involving changes to fundamental data structures) are overwritten during upgrades and must be reimplemented.

**Customization Advantages:**

- Improves user acceptance
- Offers the potential to obtain competitive advantage vis-à-vis companies using only standard features.

**Customization Disadvantages:**

- Increases time and resources required to both implement and maintain.
- Inhibits seamless communication between suppliers and customers who use the same ERP system uncustomized.
- Over reliance on customization undermines the principles of ERP as a standardizing software platform.

### Extensions

ERP systems can be extended with third-party software. ERP vendors typically provide access to data and functionality through published interfaces. Extensions offer features such as:

- archiving, reporting and republishing;
- capturing transactional data, e.g. using scanners, dills or RFID

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- access to specialized data/capabilities, such as syndicated marketing data and associated trend analytics.
- advanced planning and scheduling (APS)

Data migration

Data migration is the process of moving/copying and restructuring data from an existing system to the ERP system. Migration is critical to implementation success and requires significant planning. Unfortunately, since migration is one of the final activities before the production phase, it often receives insufficient attention. The following steps can structure migration planning:

- Identify the data to be migrated
- Determine migration timing
- Generate the data templates
- Freeze the toolset
- Decide on migration-related setups
- Define data archiving policies and procedures.

## Advantages

The fundamental advantage of ERP is that integrating the myriad processes by which businesses operate saves time and expense. Decisions can be made more quickly and with fewer errors. Data becomes visible across the organization. Tasks that benefit from this integration include:

- Sales forecasting, which allows inventory optimization
- Chronological history of every transaction through relevant data compilation in every area of operation.
- Order tracking, from acceptance through fulfillment
- Revenue tracking, from invoice through cash receipt
- Matching purchase orders (what was ordered), inventory receipts (what arrived), and costing (what the vendor invoiced)

ERP systems centralize business data, bringing the following benefits:

- They eliminate the need to synchronize changes between multiple systems-consolidation of finance, marketing and sales, human resource, and manufacturing applications
- They bring legitimacy and transparency in each bit of statistical data.
- They enable standard product naming/coding.
- They provide a comprehensive enterprise view (no "islands of information"). They make real-time information available to management anywhere, any time to make proper decisions.
- They protect sensitive data by consolidating multiple security systems into a single structure.

## Disadvantages

- Customization is problematic.
- Re-engineering business processes to fit the ERP system may damage competitiveness and/or divert focus from other critical activities
- ERP can cost more than less integrated and/or less comprehensive solutions.
- High switching costs associated with ERP can increase the ERP vendor's negotiating power which can result in higher support, maintenance, and upgrade expenses.
- Overcoming resistance to sharing sensitive information between departments can divert management attention.
- Integration of truly independent businesses can create unnecessary dependencies.
- Extensive training requirements take resources from daily operations.
- Due to ERP's architecture (OLTP, On-Line Transaction Processing) ERP systems are not well suited for production planning and supply chain management (SCM)

The limitations of ERP have been recognized sparking new trends in ERP application development, the four significant developments being made in ERP are, creating a more flexible ERP, Web-Enable ERP, Inter enterprise ERP and e-Business Suites, each of which will potentially address the failings of the current ERP.

## 5.11 JUST IN TIME

Just in time (JIT) is a production strategy that strives to improve a business return on investment by reducing in-process inventory and associated carrying costs. Just-in-time production method is also called the Toyota Production System. To meet JIT objectives, the process relies on signals or Kanban (?? Kanban?) between different points in the process, which tell production when to make the next part. Kanban are usually 'tickets' but can be simple visual signals, such as the presence or absence of a part on a shelf. Implemented correctly, JIT focuses on continuous improvement and can improve a manufacturing organization's return on investment, quality, and efficiency. To achieve continuous improvement key areas of focus could be flow, employee involvement and quality.

Quick notice that stock depletion requires personnel to order new stock is critical to the inventory reduction at the center of JIT. This saves warehouse space and costs. However, the complete mechanism for making this work is often misunderstood.

For instance, its effective application cannot be independent of other key components of a lean manufacturing system or it can "...end up with the opposite of the desired result." In recent years manufacturers have continued to try to hone forecasting methods such as applying a trailing 13 week average as a better predictor for JIT planning; however, some research demonstrates that basing JIT on the presumption of stability is inherently flawed.

The philosophy of JIT is simple: inventory is waste. JIT inventory systems expose hidden cost of keeping inventory, and are therefore not a simple solution for a company to adopt. The company must follow an array of new methods to manage

*Check Your Progress*

3) What do you mean by just-in-time?
4) What is the process of Data Migration?

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the consequences of the change. The ideas in this way of working come from many different disciplines including statistics, industrial engineering, production management, and behavioral science. The JIT inventory philosophy defines how inventory is viewed and how it relates to management.

Inventory is seen as incurring costs, or waste, instead of adding and storing value, contrary to traditional accounting. This does not mean to say JIT is implemented without awareness that removing inventory exposes pre-existing manufacturing issues. This way of working encourages businesses to eliminate inventory that does not compensate for manufacturing process issues, and to constantly improve those processes to require less inventory. Secondly, allowing any stock habituates management to stock keeping. Management may be tempted to keep stock to hide production problems. These problems include backups at work centers, machine reliability, and process variability, lack of flexibility of employees and equipment, and inadequate capacity.

In short, the Just-in-Time inventory system focus is having "the right material, at the right time, at the right place, and in the exact amount"-Ryan Grabosky, without the safety net of inventory. The JIT system has broad implications for implementers.

**Transaction cost approach**

JIT reduces inventory in a firm. However, a firm may simply be outsourcing their input inventory to suppliers, even if those suppliers don't use Just-in-Time (Naj 1993). Newman (1994) investigated this effect and found that suppliers in Japan charged JIT customers, on average, a 5% price premium.

**Environmental concerns**

During the birth of JIT, multiple daily deliveries were often made by bicycle. Increased scale has required a move to vans and Lorries (trucks). Cusumano (1994) highlighted the potential and actual problems this causes with regard to gridlock and burning of fossil fuels. This violates three JIT waste guidelines:

1. Time-wasted in traffic jams
2. Inventory-specifically pipeline (in transport) inventory
3. Scrap-fuel burned while not physically moving

**Price volatility**

JIT implicitly assumes a level of input price stability that obviates the need to buy parts in advance of price rises. Where input prices are expected to rise, storing inventory may be desirable.

**Quality volatility**

JIT implicitly assumes that input parts quality remains constant over time. If not, firms may hoard high-quality inputs. As with price volatility, a solution is to work with selected suppliers to help them improve their processes to reduce variation and costs. Longer term price agreements can then be negotiated and agreed-on quality standards made the responsibility of the supplier. Fixing up of standards for volatility of quality according to the quality circle

**Demand stability**

Karmarker (1989) highlights the importance of relatively stable demand, which helps ensure efficient capital utilization rates. Karmarker argues that without significantly stable demand, JIT becomes untenable in high capital cost production.

**Supply stability**

In the U.S., the 1992 railway strikes caused General Motors to idle a 75,000-worker plant because they had no supply.

**JIT implementation design**

Based on a diagram modeled after the one used by Hewlett-Packard's Boise plant to accomplish its JIT program.

1) F Design Flow Process
   - F Redesign/relay out for flow
   - L Reduce lot sizes
   - O Link operations
   - W Balance workstation capacity
   - M Preventive maintenance
   - S Reduce setup Times
2) Q Total Quality Control
   - C worker compliance
   - I Automatic inspection
   - M quality measures
   - M fail-safe methods
   - W Worker participation
3) S Stabilize Schedule
   - S Level schedule
   - W Establish freeze windows
   - UC Underutilize Capacity
4) K Kanban Pull System
   - D Demand pull
   - B Backflush
   - L Reduce lot sizes
5) V Work with Vendors
   - L Reduce lead time
   - D Frequent deliveries
   - U Project usage requirements
   - Q Quality expectations

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6) I Further Reduce Inventory in Other Areas
   - S Stores
   - T Transit
   - C Implement carrousel to reduce motion waste
   - C Implement conveyor belts to reduce motion waste
7) P Improve Product Design
   - P Standard production configuration
   - P Standardize and reduce the number of parts
   - P Process design with product design
   - Q Quality expectations

Effects

A surprising effect was that factory response time fell to about a day. This improved customer satisfaction by providing vehicles within a day or two of the minimum economic shipping delay.

Also, the factory began building many vehicles to order, eliminating the risk they would not be sold. This improved the company's return on equity.

Since assemblers no longer had a choice of which part to use, every part had to fit perfectly. This caused a quality assurance crisis, which led to a dramatic improvement in product quality. Eventually, Toyota redesigned every part of its vehicles to widen tolerances, while simultaneously implementing careful statistical controls for quality control. Toyota had to test and train parts suppliers to assure quality and delivery. In some cases, the company eliminated multiple suppliers.

When a process or parts quality problem surfaced on the production line, the entire production line had to be slowed or even stopped. No inventory meant a line could not operate from in-process inventory while a production problem was fixed. Many people in Toyota predicted that the initiative would be abandoned for this reason. In the first week, line stops occurred almost hourly. But by the end of the first month, the rate had fallen to a few line stops per day. After six months, line stops had so little economic effect that Toyota installed an overhead pull-line, similar to a bus bell-pull, that let any worker on the line order a line stop for a process or quality problem. Even with this, line stops fell to a few per week.

The result was a factory that has been studied worldwide. It has been widely emulated, but not always with the expected results, as many firms fail to adopt the full system.

The just-in-time philosophy was also applied to other segments of the supply chain in several types of industries. In the commercial sector, it meant eliminating one or all of the warehouses in the link between a factory and a retail establishment. Examples in sales, marketing, and customer service involve applying information systems and mobile hardware to deliver customer information as needed, and reducing waste by video conferencing to cut travel time.

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**Benefits**

Main benefits of JIT include:

- Reduced setup time. Cutting setup time allows the company to reduce or eliminate inventory for "changeover" time. The tool used here is SMED (single-minute exchange of dies).
- The flow of goods from warehouse to shelves improves. Small or individual piece lot sizes reduce lot delay inventories, which simplifies inventory flow and its management.
- Employees with multiple skills are used more efficiently. Having employees trained to work on different parts of the process allows companies to move workers where they are needed.
- Production scheduling and work hour consistency synchronized with demand. If there is no demand for a product at the time, it is not made. This saves the company money, either by not having to pay workers overtime or by having them focus on other work or participate in training.
- Increased emphasis on supplier relationships. A company without inventory does not want a supply system problem that creates a part shortage. This makes supplier relationships extremely important.
- Supplies come in at regular intervals throughout the production day. Supply is synchronized with production demand and the optimal amount of inventory is on hand at any time. When parts move directly from the truck to the point of assembly, the need for storage facilities is reduced.
- Minimizes storage space needed.
- Smaller chance of inventory breaking/expiring.

## 5.12 Problems

### Within a JIT system

Just-in-time operation leaves suppliers and downstream consumers open to supply shocks and large supply or demand changes. For internal reasons, Ohno saw this as a feature rather than a bug. He used an analogy of lowering the water level in a river to expose the rocks to explain how removing inventory showed where production flow was interrupted. Once barriers were exposed, they could be removed. Since one of the main barriers was rework, lowering inventory forced each shop to improve its own quality or cause a holdup downstream. A key tool to manage this weakness is production leveling to remove these variations. Just-in-time is a means to improving performance of the system, not an end.

Very low stock levels means shipments of the same part can come in several times per day. This means Toyota is especially susceptible to flow interruption. For that reason, Toyota uses two suppliers for most assemblies. As noted in Liker (2003), there was an exception to this rule that put the entire company at risk because of the 1997 Aisin fire. However, since Toyota also makes a point of maintaining high quality relations with its entire supplier network, several other suppliers immediately took up production of the Aisin-built parts by using existing capability and documentation. Thus, a strong, long-term relationship with a few

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suppliers is better than short-term, price-based relationships with many competing suppliers. Toyota uses this long-term relationship to send Toyota staff to help suppliers improve their processes. These interventions have been going on for twenty years and have created a more reliable supply chain, improved margins for Toyota and suppliers, and lowered prices for customers. Toyota encourages their suppliers to use JIT with their own suppliers.

## Kanban

Kanban (カンバン) , literally meaning "signboard" or "billboard", is a concept related to lean 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 of the 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 highlighted problem areas.[4]

## Origins

In the late 1940s, Toyota began studying supermarkets with a view to applying store and shelf-stocking techniques to the factory floor, based on the idea that in a supermarket, customers get what they need at the needed time, and in the needed amount. Furthermore, the supermarket only stocks what it believes it will sell, and customers only take what they need because future supply is assured. This led Toyota to view a process as being a customer of preceding processes, and the preceding processes as a kind of store. The customer process goes to this store to get needed components, and the store restocks. Originally, as in supermarkets, signboards were used to guide "shopper" processes to specific restocking locations.

Kanban uses the rate of demand to control the rate of production, passing demand from the end customer up through the chain of customer-store processes. In 1953, Toyota applied this logic in their main plant machine shop.

## Operation

An important determinant of the success of production scheduling based on "pushing" the demand is the quality of the demand forecast that can receive such "push."

Kanban, by contrast, is part of an approach of receiving the "pull" from the demand. Therefore, the supply or production is determined according to the actual demand of the customers. In contexts where supply time is lengthy and demand is difficult to forecast, the best one can do is to respond quickly to observed demand. This is exactly what a Kanban system can help with: It is used as a demand signal that immediately propagates through the supply chain. This can be used to ensure that intermediate stocks held in the supply chain are better managed, usually smaller. Where the supply response cannot be quick

enough to meet actual demand fluctuations, causing significant lost sales, then stock building may be deemed as appropriate which can be achieved by issuing more Kanban. Taiichi Ohno states that to be effective Kanban must follow strict rules of use (Toyota, for example, has six simple rules, below) and that close monitoring of these rules is a never-ending task to ensure that the Kanban does what is required.

### Kanban cards

Kanban cards are a key component of Kanban that uses cards to signal the need to move materials within a manufacturing or production facility or move materials from an outside supplier to the production facility.

The Kanban card is, in effect, a message that signals depletion of product, parts or inventory that when received will trigger the replenishment of that product, part or inventory. Consumption drives demand for more. Demand for more is signaled by Kanban card. Kanban cards therefore help to create a demand-driven system. It is widely espoused by proponents of Lean production and manufacturing that demand-driven systems lead to faster turnarounds in production and lower inventory levels, helping companies implementing such systems to be more competitive.

Kanban cards, in keeping with the principles of Kanban, should simply convey the need for more materials. A red card lying in an empty parts cart would easily convey to whomever it would concern that more parts are needed.

In the last few years, electronic Kanban systems, which send Kanban signals electronically, have become more widespread. While this is leading to a reduction in the use of Kanban cards in aggregate, it is common in modern Lean production facilities to still find widespread usage of Kanban cards. In Oracle ERP, Kanban is used for signaling demand to vendors through email notifications. When stock of a particular component is depleted by quantity assigned on Kanban card, A "Kanban trigger" is created which may be manual or automatic, a purchase order is released with predefined quantity for the vendor defined on the card, and the vendor is expected to dispatch material within lead time. This system is also available in enterprise resource planning software such as SAP ERP or Microsoft Dynamics AX.

### Toyota's six rules

- Do not send defective product to the subsequent process
- The subsequent process comes to withdraw only what is needed
- Produce only the exact quantity withdrawn by the subsequent process
- Level the production
- Kanban is a means to fine tuning
- Stabilize and rationalize the process

### Three-bin system

A simple example of the Kanban system implementation might be a "three-bin system" for the supplied parts (where there is no in-house manufacturing) - one bin on the factory floor (demand point), one bin in the factory store, and one

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bin at the suppliers' store. The bins usually have a removable card that contains the product details and other relevant information - the Kanban card.

When the bin on the factory floor becomes empty, i.e., there is demand for parts, the empty bin and Kanban cards are returned to the factory store. The factory store then replaces the bin on the factory floor with a full bin, which also contains a Kanban card. The factory store then contacts the supplier's store and returns the now-empty bin with its Kanban card. The supplier's inbound product bin with its Kanban card is then delivered into the factory store completing the final step to the system. Thus the process will never run out of product and could be described as a loop, providing the exact amount required, with only one spare so there will never be an oversupply. This 'spare' bin allows for the uncertainty in supply, use and transport that are inherent in the system. The secret to a good Kanban system is to calculate how many Kanban cards are required for each product. Most factories using Kanban use the colored board system (Heijunka Box). This consists of a board created especially for holding the Kanban cards.

### Electronic Kanban systems

Many manufacturers have implemented electronic Kanban systems. Electronic Kanban systems, or E-Kanban systems, help to eliminate common problems such as manual entry errors and lost cards. E-Kanban systems can be integrated into enterprise resource planning (ERP) systems. Integrating E-Kanban systems into ERP systems allows for real-time demand signaling across the supply chain and improved visibility. Data pulled from E-Kanban systems can be used to optimize inventory levels by better tracking supplier lead and replenishment times.

### CASE STUDY - JIT in Action

A new phenomenon called 'Apparel on Demand' is slowly making its presence felt. It is an extension of JIT linking retailers and manufacturers for a just-in-time responsiveness. NaaR Clothing Inc., promoted by a young management graduate has recently ventured into the business of making reasonably priced custom jeans for women. It has partnered with many stores selling women garments. In the stores, women are electronically measured and information like colour, fabric, style, etc., is recorded. The information reaches the NaaR manufacturing facility at Ahmedabad almost immediately through a state-of-the-art information system. NaaR guarantees delivery of the custom jeans within 10 days. With the

growing acceptance of jeans among the women in India, especially in the urban areas, the market for women's jeans is growing at a fast pace. NaaR with its unique business model hopes to garner a significant share of this market. The promoter of NaaR along with her top executives is confident that their concept of JIT jeans would work.

(a) Do you think NaaR's strategy would work? Why or why not? What is the importance of retailers in its business strategy?

(b) Will customers wait for 10 days to have the jeans delivered? What can NaaR do to compete on customer service if delivery takes this much time?

(c) Comment on the necessity of a robust supply chain in the context of NaaR Clothing Inc.

## 5.13 SUMMARY

Capacity planning has seen an increased emphasis due to the financial benefits of the efficient use of capacity plans within material requirements planning systems and other information systems. Insufficient capacity can quickly lead to deteriorating delivery performance, unnecessarily increase work-in-process, and frustrate sales personnel and those in manufacturing. However, excess capacity can be costly and unnecessary. The inability to properly manage capacity can be a barrier to the achievement of maximum firm performance. In addition, capacity is an important factor in the organization's choice of technology.

Capacity is usually assumed to mean the maximum rate at which a transformation system produces or processes inputs. Sometimes, this rate may actually be "all at once"s with the capacity of an airplane. A more usable definition of capacity would be the volume of output per elapsed time and the production capability of a facility.

Capacity planning is the process used to determine how much capacity is needed (and when) in order to manufacture greater product or begin production of a new product. A number of factors can affect capacity number of workers, ability of workers, number of machines, waste, scrap, defects, errors, productivity, suppliers, government regulations, and preventive maintenance. Capacity planning is relevant in both the long term and the short term. However, there are different issues at stake for each.

ERP (enterprise resource planning) is an industry term for the broad set of activities that helps a business manages the important parts of its business. The information made available through an ERP system provides visibility for key performance indicators (KPIs) required for meeting corporate objectives. ERP software applications can be used to manage product planning, parts purchasing, inventories, interacting with suppliers, providing customer service, and tracking orders. ERP can also include application modules for the finance and human resources aspects of a business. Typically, an ERP system uses or is integrated with a relational database system.

## ANSWERS TO 'CHECK YOUR PROGRESS'

(i) Manufacturing resource planning (MRP II) is defined by as a method for the effective planning of all resources of a manufacturing company.

(ii) Enterprise resource planning (ERP) systems integrate internal and external management information across an entire organization, embracing finance/ accounting, manufacturing, sales and service, customer relationship management, etc.

(iii) Just in time (JIT) is a production strategy that strives to improve a business return on investment by reducing in-process inventory and associated carrying costs.

(iv) ERP's scope usually implies significant changes to staff work processes and practices.

(v) Data migration is the process of moving/copying and restructuring data from an existing system to the ERP system.

NOTES

## 5.14 TEST YOURSELF

1. Explain what is meant by Capacity planning and the strategies related to it.
2. Describe the historical evolution of MRP and MRP II.
3. What is the general concept of MRP II?
4. Highlight the various benefits associated with MRP II.
5. What is the use of the concept of Just in Time in modern day business?
6. What do you understand by the mechanism of Kanban?

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## 5.16 FURTHER READING

- *Production and Material Management: Cundiff and Govani*

# 6 MATERIAL PLANNING (MP) OR MATERIAL REQUIREMENT PLANNING (MRP) AND BUDGETING

*The Chapter Covers :*



***Learning Objectives:***

After going through this chapter, you should be able to

- Explain Material Planning Function and Objective
- Describe techniques of material planning
- Clarify Stores management
- Understand Codification
- Learn Standardization

NOTES

The objective of materials management is to have the right material required for manufacturing, or production, in the right amount, at the right place, and at the right time, and, as we have already noted, this implies that the what, how much, and when of material requirements must be determined first. This is the basic objective of the materials planning and budgeting function. The questions that must be answered are the following:

- Which material inputs must we get?

Note: The inputs required are dependent on the outputs/end products planned to be manufactured.

- How much of each of these inputs do we need, and based on how much is available in stores and/or has already been ordered (inventory on hand and or order), how much of each of these should be ordered? The gross requirements of each of the required material inputs are calculated first and the net requirements are derived by subtracting from it the on hand and on order inventory.
- When should the orders for each of these materials be placed?

Material planning is a scientific technique of determining in advance the requirements of raw materials, ancillary parts and components, spares etc. as directed by the production programme. It is a sub-system in the overall planning activity. There are many factors, which influence the activity of material planning. These factors can be classified as macro and micro systems.

1) Macro factors: Some of the micro factors which affect material planning, are price trends, business cycles Govt. import policy etc.
2) Micro factors: Some of the micro factors that affect material planning are plant capacity utilization, rejection rates, lead times, inventory levels, working capital, delegation of powers and communication.

The importance of material in manufacturing concern needs the explanation because in its absence production is not possible. Moreover it affects the efficiency of all machines, money & marketing division of an industry. But there are so many problems awarded with the management of materials, such as investment in materials idle funds, storage of obsolescence problem, wastage of material in handling etc. which require immediate attention of management. So that the most of production may be reduced to the minimum & the quality of product may be maintained. As material consume lion's share of the investment and that too with a possibility of turnover, its efficient management consumed to the profitability of the organisation.

Material planning is the important activity of materials managements. It should also be noticed that inventory 'Control' is an integral part of the materials production material.

Material planning means to develop a purchasing procedure. For procurement of materials, it is essential to know how much quantity is required. Based on these information the procurement program is drawn up & financial provision is made materials planning & programming is also essential to place the orders well in advance (lead time) so that delivery at right time is ensured.

The starting point of the planning of materials procurement is the production schedules & bill of materials stores & spare parts, planning is done with the help of forecasted demand & the consumption patterns. Based on the annual forecast, production schedules are made. Working backwards on the schedules the dates on which the difference materials must be in plant, are calculated. Appropriate factor of safety should be used in working out latest date of arrival. The quantities required are also calculated with he help of bill of materials.

Materials planning for project work can be done in the similar way, in such cases use of network techniques can he made to arrive at later date of materials.

In batch manufacturing, where items are assembled in batches, certain components may be required in large quantities at infrequent intervals i.e. to suit batch assembly schedule. There will be little benefit in maintaining stocks of all parts & items at all items since at most times these stocks will not be drawn upon. Thus the procedure can be developed by which those items required for assembly are available at the time required stocks of these items are not maintained or are maintained at a far lower level.

Thus materials planning activity acts as a effective link between the purchasing or procurement & the manufacturing function. It requires the knowledge of....

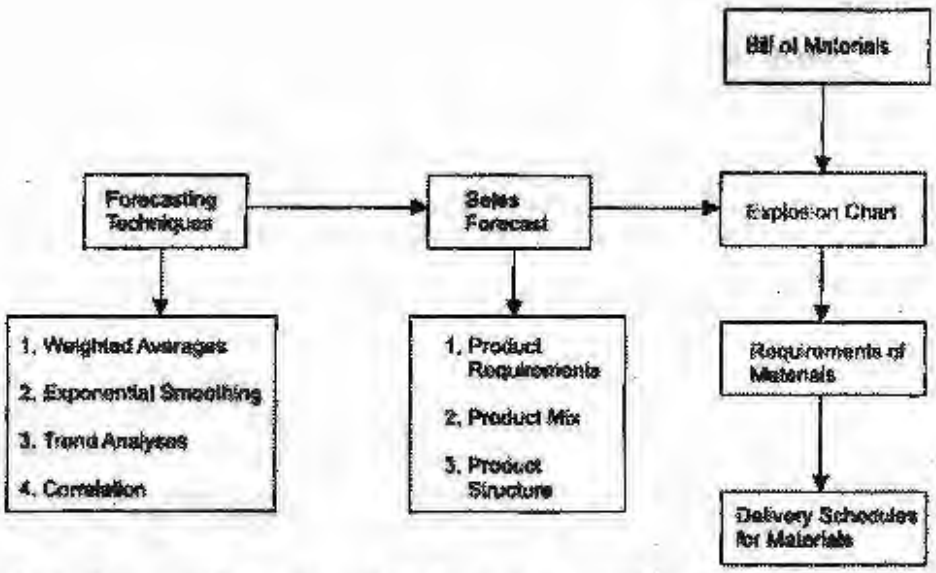
- Bill of material quantity, quality & specification of material
- Production of Assembly schedule.
- Supply lead times & dependability.
- Manufacturing capacity.
- Overall economy.

## 6.2 Material Planning Functions and Objective:

1) Translation of the sales projections inro long term requirements.
2) On the basis of updated production plan adjusted to the latest sales demand to adjust the materials accordingly.
3) To project the facilities required for the materials management.
4) Setting up of consumption standards, for working out requirements.
5) To perform value analysis to determine the intrinsic worth of materials.
6) To decide whether to Make or Buy.
7) To highlight exception & priorities.
8) To keep inventories as low as possible.
9) To procure parts as & when needed by the production/assembly schedule.

## 6.3 Techniques of Material Planning:

One of the techniques of material planning is bill of material explosion. Material planning through bill of material explosion is shown below in figure.




The basis for material planning is the forecast demand for the end products. Forecasting techniques such as weighted average method, exponential smoothening and time series models are used for the same. Once the demand forecast is made, it is possible go through the exercise of material planning.

Bill of materials is a document which shows list of materials required, unit consumption location code for a given product. An explosive chart is a series of bill of material grouped in a matrix form so that combined requirements for different components can be done requirements of various materials are arrives at from the demand forecast, using bill of materials, through explosion charts. Thus material requirement plan will lead to be the development of delivery schedule of the materials and purchasing of those material requirements.

## 6.4 Scope of Materials Planning in Manufacturing

The basic function of MRP system includes inventory control, bill of material processing and elementary scheduling. MRP helps organizations to maintain low inventory levels. It is used to plan manufacturing, purchasing and delivering activities.

"Manufacturing organizations, whatever their products, face the same daily practical problem - that customers want products to be available in a shorter time than it takes to make them. This means that some level of planning is required."

Companies need to control the types and quantities of materials they purchase, plan which products are to be produced and in what quantities and ensure that they are able to meet current and future customer demand, all at the lowest possible cost. Making a bad decision in any of these areas will make the company lose money. A few examples are given below:

- If company purchases insufficient quantities of an item used in manufacturing (or the wrong item) it may be unable to meet contract obligations to supply products on time.
- If a company purchases excessive quantities of an item, money is wasted - the excess quantity ties up cash while it remains as stock and may never even be used at all.

- Beginning production of an order at the wrong time can cause customer deadlines to be missed.

MRP is a tool to deal with these problems. It provides answers for several questions:

- What items are required?
- How many are required?
- When are they required?

MRP can be applied both to items that are purchased from outside suppliers and to sub-assemblies, produced internally, that are components of more complex items.

The data that must be considered include:

- The end item (or items) being created. This is sometimes called Independent Demand or Level "0 on BOM (Bill of materials).
- How much is required at a time.
- When the quantities are required to meet demand.
- Shelf life of stored materials.
- Inventory status records. Records of net materials available for use already in stock (on hand) and materials on order from suppliers.
- Bills of materials. Details of the materials, components and sub-assemblies required to make each product.
- Planning Data. This includes all the restraints and directions to produce the end items. This includes such items as: Routings, Labor and Machine Standards, Quality and Testing Standards, Pull/Work Cell and Push commands, Lot sizing techniques (i.e. Fixed Lot Size, Lot-For-Lot, and Economic Order Quantity), Scrap Percentages, and other inputs.

## 6.5 Problems with MRP systems

- The major problem with MRP systems is the integrity of the data. If there are any errors in the inventory data, the bill of materials (commonly referred to as 'BOM') data, or the master production schedule, then the output data will also be incorrect (colloquially, "GIGO": Garbage In, Garbage Out). Data integrity is also affected by inaccurate cycle count adjustments, mistakes in receiving input and shipping output, scrap not reported, waste, damage, box count errors, supplier container count errors, production reporting errors, and system issues. Many of these types of errors can be minimized by implementing pull systems and using bar code scanning. Most vendors in this type of system recommend at least 99% data integrity for the system to give useful results.
- Another major problem with MRP systems is the requirement that the user specify how long it will take for a factory to make a product from its component parts (assuming they are all available). Additionally, the system design also assumes that this "lead time" in manufacturing will be the same each time the item is made, without regard to quantity being made, or other items being made simultaneously in the factory.

*Check Your Progress*

i. Explain Codification?
ii. Define Standardization?
iii. What do you mean by material planning?

- A manufacturer may have factories in different cities or even countries. It is not good for an MRP system to say that we do not need to order some material, because we have plenty thousands of miles away. The overall ERP system needs to be able to organize inventory and needs by individual factory, and intercommunicate the needs in order to enable each factory to redistribute components, so as to serve the overall enterprise.
- This means that other systems in the enterprise need to work properly, both before implementing an MRP system and in the future. For example, systems like variety reduction and engineering, which makes sure that product comes out right first time (without defects), must be in place.
- Production may be in progress for some part, whose design gets changed, with customer orders in the system for both the old design, and the new one, concurrently. The overall ERP system needs to have a system of coding parts such that the MRP will correctly calculate needs and tracking for both versions. Parts must be booked into and out of stores more regularly than the MRP calculations take place. Note, these other systems can well be manual systems, but must interface to the MRP. For example, a 'walk around' stock intake done just prior to the MRP calculations can be a practical solution for a small inventory (especially if it is an "open store").
- The other major drawback of MRP is that takes no account of capacity in its calculations. This means it will give results that are impossible to implement due to manpower or machine or supplier capacity constraints. However this is largely dealt with by MRP II.
- Generally, MRP II refers to a system with integrated financials. An MRP II system can include finite / infinite capacity planning. But, to be considered a true MRP II system must also include financials.
- In the MRP II (or MRP2) concept, fluctuations in forecast data are taken into account by including simulation of the master production schedule, thus creating a long-term control. A more general feature of MRP2 is its extension to purchasing, to marketing and to finance (integration of all the function of the company), ERP has been the next step.

## 6.6 STORES MANAGEMENT:

Stores play a vital role in the operations of company. It is in direct touch with the user departments in its day-to-day activities. The most important purpose served by the stores is to provide uninterrupted service to the manufacturing divisions. Further, stores are often equated directly with money, as money is locked up in the stores.

## 6.7 FUNCTIONS OF STORES:

The functions of stores can be classified as follows:

1) To receive raw materials, components, tools, equipment's and other items and account for them.
2) To provide adequate and proper storage and preservation to the various items.
3) To meet the demands of the consuming departments by proper issues and account for the consumption.

4) To minimize obsolescence, surplus and scrap through proper codification, preservation and handling.

5) To highlight stock accumulation, discrepancies and abnormal consumption and effect control measures.

6) To ensure good house keeping so that material handling, material preservation, stocking, receipt and issue can be done adequately.

7) To assist in verification and provide supporting information for effective purchase action.

## 6.8 CODIFICATION:

Coding is the main function of specifying a unique identification to the material in the stores or in inventory. Coding is essential for requisitioning materials for the operational departments, placing orders, receiving materials from the suppliers and having unique record for each material in the stores. It also helps in having good control over the inventories and pilferage of materials kept in the stores.

Unique identification of materials such as raw material, work-in-process material or finished good is a good practice. Coding is important for those plants that have varieties of raw-materials with similar nomenclature.

It is one of the functions of stores management. Codification is a process of representing each item by a number, the digit of which indicates the group, the sub-group, the type and the dimension of the item. Many organizations in the public and private sectors, railways have their own system of codification, varying from eight to thirteen digits. The first two digits represents the major groups, such as raw materials, spare parts, sub-contracted items, hardware items, packing material, tools, oil, stationery etc. The next two digits indicate the sub-groups, such as, ferrous, non-ferrous etc. Dimensional characteristics of length, width, head diameter etc. constitute further three digits and the last digit is reserved for minor variations.

Whatever may be the basis, each code should uniquely represent one item. It should be simple and capable of being understood by all. Codification should be compact, concise, consistent and flexible enough to accommodate new items. The groupings should be logical, holding similar parts near to one another. Each digit must be significant enough to represent some characteristic of the item.

## 6.9 Characteristics of good coding system:

A good coding system has the following characteristics:

- **Flexibility:** A coding system should be long lasting so that maximum benefits could be achieved. Long- term requirement of an organization should be kept in mind while applying any coding method.
- **Precision:** The codification method should imply that a unique code is given for every material. A proper and logical coding should be given to every material so that no confusion or mismanagement occurs in future.
- **Brevity:** While coding a material, the length of the code should not be very long or very short. The code should be such that the material should be easily identifiable by just looking at the code.

- **Comprehensiveness:** While classifying a material for coding, the nature of the material, name of the supplier and end users should be taken into account. The code should be such that all these factors are implemented in the code. This helps in tracking information about the material.

While coding a material, answer to the following questions should always be kept in mind:

i) Who is the user?

ii) What is the use of coding the material?

iii) Which method is the most appropriate for coding?

**Objectives of Codification:**

The objectives of a rationalized material coding system are:

1) Bringing all items together.

2) To enable putting up of any future item in its proper place.

3) To classify an item according to its characteristics.

4) To give a unique code number to each item to avoid duplication and ambiguity.

5) To reveal excessive variety and promote standardization and variety reduction.

6) To establish a common language for the identification of an item.

7) To fix essential parameters for specifying an item.

8) To specify item as per national and international standards.

9) To enable data processing and analysis.

**Advantages of Codification:**

As a result of rationalized codification, many firms have reduced the number of items. It enables systematic grouping of similar items and avoids confusion caused by long description of items since standardization of names is achieved through codification, it serves as the starting point of simplification and standardization. It helps in avoiding duplication of items and results in the minimization of the number of items, leading to accurate record. Codification enables easy recognition of an item in stores, thereby reducing clerical efforts to the minimum. If items are coded according to the sources, it is possible to bulk the items while ordering. To maximize the aforesaid advantages, it is necessary to develop the codes as concerned, namely, personnel from design, production, engineering, inspection, maintenance and materials.

## 6.10 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.

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**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 sales volume.
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.

NOTES

Benefits to Purchase and Stock Control Department:

1. Holding of stock of standard items leads to less paper work and fewer requisitions and 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, favorable purchase contracts can be made.

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:

i) Work study section is benefited with efficient break down of operations and effective work measurement.

ii) Costing can obtain better control by installing standard costing.

iii) More time is available to the supervisors to make useful records and preserve statistics.

iv) Reduced reductions and scrap.

v) Helps supervisors to run his department efficiently and effectively.

Disadvantages of Standardization:

Following are the disadvantages of standardization:

i) Reduction in choice because of reduced variety and consequently loss of business or customer.

ii) Standard once set, resist change and thus standardization may become an obstacle to progress.

iii) It tends to favour only large companies.

iv) It becomes very difficult to introduce new models because of less flexible production facilities and due to high cost of specialized production equipment.

Case Study: Problem Description

Material requirement planning (MRP) is a key element in managing resources in a manufacturing environment. MRP systems were developed to help companies manage dependent demand inventory and schedule replenishment orders. MRP systems have proven to be beneficial to many companies.

The aim of this project is to build a support system that would generate material requirements plans for a manufacturing company. This support system should be build using the principles of MRP systems. We use a simple example to show how MRP systems work; however, to learn more about these systems we refer the students to Krajewski and Ritzman (2002) and Nahmias (2000).

An MRP system translates the master production schedule (MPS), bill of materials (BOM), and inventory records into a material requirement plan that specifies the replenishment schedules of all the subassemblies, components, and raw materials needed for the final product. We illustrate the inputs of the system and the final MRP plans using an example. We consider a manufacturing company that produces chairs. We present the BOM, MPS, and MRP plans for the ladder-back chairs produced by this company (Krajewski and Ritzman, 2002).

MPS presents the lot size and due date for the final produces.


Figure 1: MPS for a Family of Chairs.

The BOM presents the components required to manufacture the final product, the parent-component relationships, and the usage quantities. Inventory records present an item's lot-size policy, lead-time, and other time-phased data. Below we present the BOM, MPS, inventory records, and the material requirements plan for a Ladder-Back Chair.

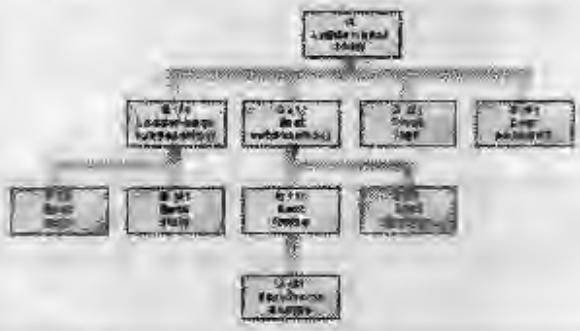

Figure 2: BOM for a Ladder-Back Chair.

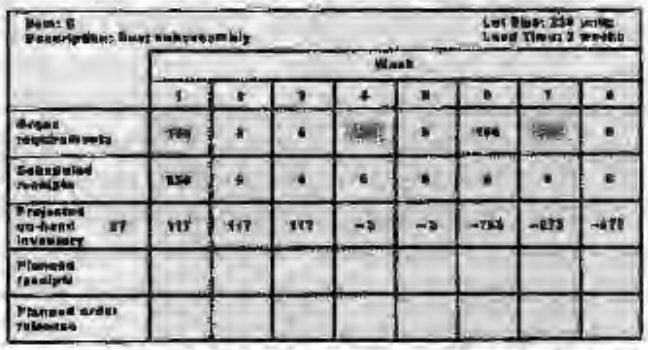

Figure 3: Inventory Records for the Seat Subassembly of the Ladder-Back Chair.

*Check Your Progress*

iv. What is stores management?

v. What are the micro factors that affect material planning?

Figure 4: Part of MRP Plans for the Ladder-Back Chair.

Excel Spreadsheets

1. Build a spreadsheet that presents for each final product the name and quantity of all the components used to produce the product.
2. Build a spreadsheet that presents for each item the amount on hand and scheduled receipts.
3. Build a spreadsheet that presents for each final product the amount and the due dates promised to customers.

User Interface

1. Build a welcome form.
2. Build a form titled "Bill of Materials." The following are suggestions to help you design this form. Insert a combo box titled "Choose a Product." The combo box allows the user to select one of the final products listed. Upon selection, a list of the components used to produce the product is displayed. The user should be able to select more than one component from the list as, more than one component may be used to produce the final product. Include two command buttons in this frame, one titled "Continue" and the other "Submit." If the user clicks on the "Continue" command button, list boxes appear, one for each component. The user selects for each item the corresponding components and submits the information. The same process continues until we have defined all parent-component relationships of the final product. If the user clicks on the "Submit" command button, then a form titled "Enter Usage Quantities" appears. This form presents all the components used by a product. Next to the name of each component, insert a text box for the user to type in the quantity used. Insert a command button that, when clicked on, submits the data and creates the bill of material for the selected product.
3. Build a form titled "Master Production Schedule." Insert a command button. When the user clicks on this button, the data about the amount of the final product due and the corresponding due date (Spreadsheet 3) are used to prepare the MPS. The MPS is presented to the user.

4. Build a form titled "Inventory Records." The frame consists of a combo box and a command button. The combo box lists the names of the final products and components. The user selects a product or a component and clicks on the command button to generate the inventory records for the selected item.
5. Build a form titled "See an Example." This form presents a simple example that demonstrates how the MRP systems work.
6. Build a form titled "Create the MRP Plans." The frame includes the following:
    a. A text box where the user types in the length of the lead-time.
    b. A combo box that allows the user to select a lot-sizing rule (FOQ, POQ, or L4L).
    c. A command button that, when clicked on, uses the BOM, MPS, inventory records, lead-time, and lot-sizing rules to produce the MRP plans.
7. Build a form titled "Reports." The form has a number of option buttons and a command button. The option buttons allow the user to select one of the reports created. When the user clicks on the command button, the selected report is opened.

Design a logo for this project. Insert this logo in the forms created above. Pick a background color and a font color for the forms created. Include the following in the forms created: record navigation command buttons, record operations command buttons, and form operations command buttons as needed.

**Reports**

1. Report the BOM for the final product(s) produced by the company.
2. Report the MPS for the final product(s) produced by the company.
3. Report the MRP plans created using the three different lot-sizing rules.

## 6.11 SUMMARY

**Material planning (MP) or Material Requirement Planning (MRP)** is a production planning and inventory control system used to manage manufacturing processes. Most MP systems are software-based, while it is possible to conduct MRP by hand as well.

An MP system is intended to simultaneously meet three objectives:

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

Prior to Material Planning, and before computers dominated industry, reorder-point/reorder-quantity (ROP/ROQ) type methods like EOQ had been used in manufac-

curing and inventory management. In 1964, Joseph Orlicky as a response to the TOYOTA Manufacturing Program developed Material Requirements Planning (MRP). First company to use MRP was Black & Decker in 1964, with Dick Alban as project leader. In 1978 Oliver Wight and George Plossl then developed MRP into manufacturing resource planning (MRP II). Orlicky'Ps book is entitled The New Way of Life in Production and Inventory Management (1975). By 1975, MRP was implemented in 150 companies. This number had grown to about 8,000 by 1981. In the 1980s, Joe Orlicky's MRP evolved into Oliver Wight's manufacturing resource planning (MRP II) which brings master scheduling, rough-cut capacity planning, capacity requirements planning, S&OP in 1983 and other concepts to classical MRP. By 1989, about one third of the software industry was MRP II software sold to American industry ($1.2 billion worth of software).

## ANSWERS TO 'CHECK YOUR PROGRESS'

(i) Coding is the main function of specifying a unique identification to the material in the stores or in inventory.

(ii) Standardization means producing maximum variety of products from the minimum variety of materials, parts, tools and processes.

(iii) Material planning means to develop a purchasing procedure. For procurement of materials, it is essential to know how much quantity is required.

## 6.12 TEST YOURSELF

1) What do you mean by Material Planning?

2) What are the functions and objectives of Material Planning?

3) What are the techniques of Material Planning?

4) Describe the term 'Stores Management'.

5) What do you mean by Codification? Explain its objectives and advantages.

6) What are essential characteristics of good coding system?

7) Write a short note on Standardization.

## 6.13 REFERENCES


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- Aswathappa, K., & Bhat, K. S. (2020). Production and operations management (2nd ed.). Himalaya Publishing House.
- Balasubramanian, K. (2018). Operations management. Vikas Publishing.


## 6.14 FURTHER READING

- *Production and Material Management Cundiff and Govani*

# BLOCK III

# 7 INVENTORY MANAGEMENT

NOTES

***The Chapter Covers :***



***Learning Objectives:***

After going through this chapter, you should be able to

- Explain Inventory Management
- Explain various types of inventory
- Describe Principle of Inventory Proportionality
- Discuss on inventory credit and inventory investment
- Define inventory management software's

NOTES

# 7.1 INTRODUCTION

Inventory means a list compiled for some formal purpose, such as the details of an estate going to probate, or the contents of a house let furnished. This remains the prime meaning in British English. In the USA and Canada the term has developed from a list of goods and materials to the goods and material available in stock by a business; and this has become the primary meaning of the term in North American English, equivalent to the term "stock" in British English. In accounting, inventory or stock is considered an asset.

## 7.2 What is Inventory Management?

Inventory management is the process of efficiently overseeing the constant flow of units into and out of an existing inventory. This process usually involves controlling the transfer in of units in order to prevent the inventory from becoming too high, or dwindling to levels that could put the operation of the company into jeopardy. Competent inventory management also seeks to control the costs associated with the inventory, both from the perspective of the total value of the goods included and the tax burden generated by the cumulative value of the inventory.

Balancing the various tasks of inventory management means paying attention to three key aspects of any inventory. The first aspect has to do with time. In terms of materials acquired for inclusion in the total inventory, this means understanding how long it takes for a supplier to process an order and execute a delivery. Inventory management also demands that a solid understanding of how long it will take for those materials to transfer out of the inventory be established. Knowing these two important lead times makes it possible to know when to place an order and how many units must be ordered to keep production running smoothly.

Calculating what is known as buffer stock is also key to effective inventory management. Essentially, buffer stock is additional units above and beyond the minimum number required to maintain production levels. For example, the manager may determine that it would be a good idea to keep one or two extra units of a given machine part on hand, just in case an emergency situation arises or one of the units proves to be defective once installed. Creating this cushion or buffer helps to minimize the chance for production to be interrupted due to a lack of essential parts in the operation supply inventory.

Inventory management is not limited to documenting the delivery of raw materials and the movement of those materials into operational process. The movement of those materials as they go through the various stages of the operation is also important. Typically known as a goods or work in progress inventory, tracking materials as they are used to create finished goods also helps to identify the need to adjust ordering amounts before the raw materials inventory gets dangerously low or is inflated to an unfavorable level.

Finally, inventory management has to do with keeping accurate records of finished goods that are ready for shipment. This often means posting the production of newly completed goods to the inventory totals as well as subtracting the most recent shipments of finished goods to buyers. When the company has a return policy in place, there is usually a sub-category contained in the finished goods inventory to

account for any returned goods that are reclassified as refurbished or second grade quality. Accurately maintaining figures on the finished goods inventory makes it possible to quickly convey information to sales personnel as to what is available and ready for shipment at any given time.

In addition to maintaining control of the volume and movement of various inventories, inventory management also makes it possible to prepare accurate records that are used for accessing any taxes due on each inventory type. Without precise data regarding unit volumes within each phase of the overall operation, the company cannot accurately calculate the tax amounts. This could lead to underpaying the taxes due and possibly incurring stiff penalties in the event of an independent audit.

## 7.3 Business Inventory

**The reasons for keeping stock**

There are three basic reasons for keeping an inventory:

1. **Time** - The time lags present in the supply chain, from supplier to user at every stage, requires that you maintain certain amounts of inventory to use in this lead time. However, in practice, inventory is to be maintained for consumption during 'variations in lead time'. Lead time itself can be addressed by ordering that many days in advance.
2. **Uncertainty** - Inventories are maintained as buffers to meet uncertainties in demand, supply and movements of goods.
3. **Economies of scale** - Ideal condition of "one unit at a time at a place where a user needs it, when he needs it" principle tends to incur lots of costs in terms of logistics. So bulk buying, movement and storing brings in economies of scale, thus inventory.

All these stock reasons can apply to any owner or product

**Special terms used in dealing with inventory**

- *Stock Keeping Unit* (SKU) is a unique combination of all the components that are assembled into the purchasable item. Therefore, any change in the packaging or product is a new SKU. This level of detailed specification assists in managing inventory.
- *Stock out* means running out of the inventory of an SKU.
- "New old stock" (sometimes abbreviated NOS) is a term used in business to refer to merchandise being offered for sale that was manufactured long ago but that has never been used. Such merchandise may not be produced anymore, and the new old stock may represent the only market source of a particular item at the present time.

**Typology**

1. Buffer/safety stock
2. Cycle stock (Used in batch processes, it is the available inventory, excluding buffer stock)

3. De-coupling (Buffer stock held between the machines in a single process which serves as a buffer for the next one allowing smooth flow of work instead of waiting the previous or next machine in the same process)
4. Anticipation stock (Building up extra stock for periods of increased demand - e.g. ice cream for summer)
5. Pipeline stock (Goods still in transit or in the process of distribution - have left the factory but not arrived at the customer yet)

Inventory examples

While accountants often discuss inventory in terms of goods for sale, organizations - manufacturers, service-providers and not-for-profits- also have inventories (fixtures, furniture, supplies, etc.) that they do not intend to sell. Manufacturers', distributors', and wholesalers' inventory tends to cluster in warehouses. Retailers' inventory may exist in a warehouse or in a shop or store accessible to customers. Inventories not intended for sale to customers or to clients may be held in any premises an organization uses. Stock ties up cash and, if uncontrolled, it will be impossible to know the actual level of stocks and therefore impossible to control them.

While the reasons for holding stock were covered earlier, most manufacturing organizations usually divide their "goods for sale" inventory into:

- Raw materials - materials and components scheduled for use in making a product.
- Work in process, WIP - materials and components that have begun their transformation to finished goods.
- Finished goods - goods ready for sale to customers.
- Goods for resale - returned goods that are salable.

For example:

*Manufacturing*

A canned food manufacturer's materials inventory includes the ingredients to form the foods to be canned, empty cans and their lids (or coils of steel or aluminum for constructing those components), labels, and anything else (solder, glue, etc.) that will form part of a finished can. The firm's work in process includes those materials from the time of release to the work floor until they become complete and ready for sale to wholesale or retail customers. This may be vats of prepared food, filled cans not yet labeled or sub-assemblies of food components. It may also include finished cans that are not yet packaged into cartons or pallets. Its finished good inventory consists of all the filled and labeled cans of food in its warehouse that it has manufactured and wishes to sell to food distributors (wholesalers), to grocery stores (retailers), and even perhaps to consumers through arrangements like factory stores and outlet centers.

## 7.4 Types of Inventory

There are two basic types: merchandising and manufacturing. Manufacturing is further divided into three more components: raw material, work in process and finished goods.

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**Merchandise inventory:** If you buy items from other artists and crafters to sell in your own gallery or shop, you'll have a merchandise inventory. Remember though - any items in your shop on consignment are not part of your inventory.

**Manufacturing inventory:** If you make your own arts and crafts, you'll have a manufacturing inventory. The term 'manufacturing' might not seem to fit a hand crafted type of business, but a quick review of the classifications within the term, will make the relationship clearer.

A manufacturing inventory consists of three different parts: raw materials, work in process and finished goods. Using a leather crafting business as my sample craft company, here are definitions and examples of the three:

**Raw materials:** Everything the crafter buys to make the product is classified as raw materials. That includes leather, dyes, snaps and grommets. The raw material inventory only includes items that have not yet been put into the production process.

**Work in process:** This includes all the leather raw materials that are in various stages of development. For the leather crafting business, it would include leather pieces cut and in the process of being sewn together and the leather belts and purse etc. that are partially constructed.

In addition to the raw materials, the work in process inventory includes the cost of the labor directly doing the work and manufacturing overhead. Manufacturing overhead is a catchall phrase for any other expenses the leather crafting business has that indirectly relate to making the products. A good example is depreciation of leather making fixed assets.

**Finished goods:** When the leather items are completely ready to sell at craft shows or other venues, they are finished goods. The finished goods inventory also consists of the cost of raw materials, labor and manufacturing overhead, now for the entire product.

Inventory is probably one of the largest costs for merchandising and manufacturing businesses.. Find out how to account for inventory regardless if you are a retailer or manufacturer.

## 7.5 Principle of Inventory Proportionality

**Purpose**

Inventory proportionality is the goal of demand-driven inventory management. The primary optimal outcome is to have the same number of days' (or hours', etc.) worth of inventory on hand across all products so that the time of run out of all products would be simultaneous. In such a case, there is no "excess inventory," that is, inventory that would be left over of another product when the first product runs out. Excess inventory is sub-optimal because the money spent to obtain it could have been utilized better elsewhere, i.e. to the product that just ran out.

The secondary goal of inventory proportionality is inventory minimization. By integrating accurate demand forecasting with inventory management, replenishment inventories can be scheduled to arrive just in time to replenish the product destined to run out first, while at the same time balancing out the inventory supply of all

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products to make their inventories more proportional, and thereby closer to achieving the primary goal. Accurate demand forecasting also allows the desired inventory proportions to be dynamic by determining expected sales out into the future; this allows for inventory to be in proportion to expected short-term sales or consumption rather than to past averages, a much more accurate and optimal outcome.

Integrating demand forecasting into inventory management in this way also allows for the prediction of the "can fit" point when inventory storage is limited on a per-product basis.

**Applications**

The technique of inventory proportionality is most appropriate for inventories that remain unseen by the consumer, as opposed to "keep full" systems where a retail consumer would like to see full shelves of the product they are buying so as not to think they are buying something old, unwanted or stale; and differentiated from the "trigger point" systems where product is reordered when it hits a certain level; inventory proportionality is used effectively by just-in-time manufacturing processes and retail applications where the product is hidden from view.

One early example of inventory proportionality used in a retail application in the United States was for motor fuel. Motor fuel (e.g. gasoline) is generally stored in underground storage tanks. The motorists do not know whether they are buying gasoline off the top or bottom of the tank, nor need they care. Additionally, these storage tanks have a maximum capacity and cannot be overfilled. Finally, the product is expensive. Inventory proportionality is used to balance the inventories of the different grades of motor fuel, each stored in dedicated tanks, in proportion to the sales of each grade. Excess inventory is not seen or valued by the consumer, so it is simply cash sunk (literally) into the ground. Inventory proportionality minimizes the amount of excess inventory carried in underground storage tanks. This application for motor fuel was first developed and implemented by Petrol Soft Corporation in 1990 for Chevron Products Company. Most major oil companies use such systems today.

**High level Inventory Management**

It seems that around 1880 there was a change in manufacturing practice from companies with relatively homogeneous lines of products to horizontally integrated companies with unprecedented diversity in processes and products. Those companies (especially in metalworking) attempted to achieve success through economies of scope – the gains of jointly producing two or more products in one facility. The managers now needed information on the effect of product-mix decisions on overall profits and therefore needed accurate product-cost information. A variety of attempts to achieve this were unsuccessful due to the huge overhead of the information processing of the time. However, the burgeoning need for financial reporting after 1900 created unavoidable pressure for financial accounting of stock and the management need to cost manage products became overshadowed. In particular, it was the need for audited accounts that sealed the fate of managerial cost accounting. The dominance of financial reporting accounting over management accounting remains to this day with few exceptions, and the financial reporting definitions of 'cost' have distorted effective management 'cost' accounting since that time. This is particularly true of inventory.

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Hence, high-level financial inventory has these two basic formulas, which relate to the accounting period:

1. Cost of Beginning Inventory at the start of the period + inventory purchases within the period + cost of production within the period = cost of goods available
2. Cost of goods available ? cost of ending inventory at the end of the period = cost of goods sold

The benefit of these formulae is that the first absorbs all overheads of production and raw material costs into a value of inventory for reporting. The second formula then creates the new start point for the next period and gives a figure to be subtracted from the sales price to determine some form of sales-margin figure.

Manufacturing management is more interested in *inventory turnover ratio or average days to sell inventory* since it tells them something about relative inventory levels.

> Inventory turnover ratio (also known as inventory turns) = cost of goods sold / Average Inventory = Cost of Goods Sold / ((Beginning Inventory + Ending Inventory) / 2)

and its inverse

> Average Days to Sell Inventory = Number of Days a Year / Inventory Turnover Ratio = 365 days a year / Inventory Turnover Ratio

This ratio estimates how many times the inventory turns over a year. This number tells how much cash/goods are tied up waiting for the process and is a critical measure of process reliability and effectiveness. So a factory with two inventory turns has six months stock on hand, which is generally not a good figure (depending upon the industry), whereas a factory that moves from six turns to twelve turns has probably improved effectiveness by 100%. This improvement will have some negative results in the financial reporting, since the 'value' now stored in the factory as inventory is reduced.

While these accounting measures of inventory are very useful because of their simplicity, they are also fraught with the danger of their own assumptions. There are, in fact, so many things that can vary hidden under this appearance of simplicity that a variety of 'adjusting' assumptions may be used. These include:

- Specific Identification
- Weighted Average Cost
- Moving-Average Cost
- FIFO and LIFO.

Inventory Turn is a financial accounting tool for evaluating inventory and it is not necessarily a management tool. Inventory management should be forward looking. The methodology applied is based on historical cost of goods sold. The ratio may not be able to reflect the usability of future production demand, as well as customer demand.

***Check Your Progress***

i. What is inventory management?

ii. What is inventory credit?

iii. Explain inventory investment?

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Business models, including Just in Time (JIT) Inventory, Vendor Managed Inventory (VMI) and Customer Managed Inventory (CMI), attempt to minimise on-hand inventory and increase inventory turns. VMI and CMI have gained considerable attention due to the success of third-party vendors who offer added expertise and knowledge that organizations may not possess.

## Accounting for Inventory

Each country has its own rules about accounting for inventory that fit with their financial-reporting rules.

For example, organizations in the U.S. define inventory to suit their needs within US Generally Accepted Accounting Practices (GAAP), the rules defined by the Financial Accounting Standards Board (FASB) (and others) and enforced by the U.S. Securities and Exchange Commission (SEC) and other federal and state agencies. Other countries often have similar arrangements but with their own GAAP and national agencies instead.

It is intentional that financial accounting uses standards that allow the public to compare firms' performance, cost accounting functions internally to an organization and potentially with much greater flexibility. A discussion of inventory from standard and Theory of Constraints-based (throughput) cost accounting perspective follows some examples and a discussion of inventory from a financial accounting perspective.

The internal costing/valuation of inventory can be complex. Whereas in the past most enterprises ran simple, one-process factories, such enterprises are quite probably in the minority in the 21st century. Where 'one process' factories exist, there is a market for the goods created, which establishes an independent market value for the good. Today, with multistage-process companies, there is much inventory that would once have been finished goods which is now held as 'work in process' (WIP). This needs to be valued in the accounts, but the valuation is a management decision since there is no market for the partially finished product. This somewhat arbitrary 'valuation' of WIP combined with the allocation of overheads to it has led to some unintended and undesirable results.

### Financial accounting

An organization's inventory can appear a mixed blessing, since it counts as an asset on the balance sheet, but it also ties up money that could serve for other purposes and requires additional expense for its protection. Inventory may also cause significant tax expenses, depending on particular countries' laws regarding depreciation of inventory, as in Thor Power Tool Company v. Commissioner.

Inventory appears as a current asset on an organization's balance sheet because the organization can, in principle, turn it into cash by selling it. Some organizations hold larger inventories than their operations require in order to inflate their apparent asset value and their perceived profitability.

In addition to the money tied up by acquiring inventory, inventory also brings associated costs for warehouse space, for utilities, and for insurance to cover staff to handle and protect it from fire and other disasters, obsolescence, shrinkage (theft and

errors), and others. Such holding costs can mount up: between a third and a half of its acquisition value per year.

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Businesses that stock too little inventory cannot take advantage of large orders from customers if they cannot deliver. The conflicting objectives of cost control and customer service often pit an organization's financial and operating managers against its sales and marketing departments. Salespeople, in particular, often receive sales-commission payments, so unavailable goods may reduce their potential personal income. This conflict can be minimized by reducing production time to being near or less than customers' expected delivery time. This effort, known as "Lean production" will significantly reduce working capital tied up in inventory and reduce manufacturing costs (See the Toyota Production System).

**Role of inventory accounting**

By helping the organization to make better decisions, the accountants can help the public sector to change in a very positive way that delivers increased value for the taxpayer's investment. It can also help to incentivize progress and to ensure that reforms are sustainable and effective in the long term, by ensuring that success is appropriately recognized in both the formal and informal reward systems of the organization.

To say that they have a key role to play is an understatement. Finance is connected to most, if not all, of the key business processes within the organization. It should be steering the stewardship and accountability systems that ensure that the organization is conducting its business in an appropriate, ethical manner. It is critical that these foundations are firmly laid. So often they are the litmus test by which public confidence in the institution is either won or lost.

Finance should also be providing the information, analysis and advice to enable the organizations' service managers to operate effectively. This goes beyond the traditional preoccupation with budgets - how much have we spent so far, how much do we have left to spend? It is about helping the organization to better understand its own performance. That means making the connections and understanding the relationships between given inputs - the resources brought to bear - and the outputs and outcomes that they achieve. It is also about understanding and actively managing risks within the organization and its activities.

**FIFO vs. LIFO accounting**

When a merchant buys goods from inventory, the value of the inventory account is reduced by the cost of goods sold (COGS). This is simple where the CoG has not varied across those held in stock; but where it has, then an agreed method must be derived to evaluate it. For commodity items that one cannot track individually, accountants must choose a method that fits the nature of the sale. Two popular methods that normally exist are: FIFO and LIFO accounting (first in - first out, last in - first out). FIFO regards the first unit that arrived in inventory as the first one sold. LIFO considers the last unit arriving in inventory as the first one sold. Which method an accountant selects can have a significant effect on net income and book value and, in turn, on taxation. Using LIFO accounting for inventory, a company generally reports lower net income and lower book value, due to the effects of inflation. This generally results in lower taxation. Due to LIFO's potential to skew

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inventory value. UK GAAP and IAS have effectively banned LIFO inventory accounting.

**Standard cost accounting**

Standard cost accounting uses ratios called efficiencies that compare the labor and materials actually used to produce a good with those that the same goods would have required under "standard" conditions. As long as similar actual and standard conditions obtain, few problems arise. Unfortunately, standard cost accounting methods developed about 100 years ago, when labor comprised the most important cost in manufactured goods. Standard methods continue to emphasize labor efficiency even though that resource now constitutes a (very) small part of cost in most cases.

Standard cost accounting can hurt managers, workers, and firms in several ways. For example, a policy decision to increase inventory can harm a manufacturing manager's performance evaluation. Increasing inventory requires increased production, which means that processes must operate at higher rates. When (not if) something goes wrong, the process takes longer and uses more than the standard labor time. The manager appears responsible for the excess, even though s/he has no control over the production requirement or the problem.

In adverse economic times, firms use the same efficiencies to downsize, right size, or otherwise reduce their labor force. Workers laid off under those circumstances have even less control over excess inventory and cost efficiencies than their managers.

Many financial and cost accountants have agreed for many years on the desirability of replacing standard cost accounting. They have not, however, found a successor.

**Theory of constraints cost accounting**

Eliyahu M. Goldratt developed the Theory of Constraints in part to address the cost-accounting problems in what he calls the "cost world." He offers a substitute, called throughput accounting, that uses throughput (money for goods sold to customers) in place of output (goods produced that may sell or may boost inventory) and considers labor as a fixed rather than as a variable cost. He defines inventory simply as everything the organization owns that it plans to sell, including buildings, machinery, and many other things in addition to the categories listed here. Throughput accounting recognizes only one class of variable cost: the truly variable costs, like materials and components, which vary directly with the quantity produced.

Finished goods inventories remain balance-sheet assets, but labor-efficiency ratios no longer evaluate managers and workers. Instead of an incentive to reduce labor cost, throughput accounting focuses attention on the relationships between throughput (revenue or income) on one hand and controllable operating expenses and changes in inventory on the other. Those relationships direct attention to the constraints or bottlenecks that prevent the system from producing more throughput, rather than to people - who have little or no control over their situations.

**Cash conversion cycle**

In management accounting, the cash conversion cycle (CCC) measures how long a firm will be deprived of cash if it increases its investment in resources in order to expand customer sales. It is thus a measure of the liquidity risk entailed by growth.

However, shortening the CCC creates its own risks: while a firm could even achieve a negative CCC by collecting from customers before paying suppliers, a policy of strict collections and lax payments is not always sustainable.

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**Definition**

$$\text{CCC} = \text{\# Days between disbursing cash and collecting cash in connection with undertaking a discrete unit of operations.}$$

$$= \frac{\text{Inventory conversion}}{\text{period}} + \frac{\text{Receivables conversion}}{\text{period}} - \frac{\text{Payables conversion}}{\text{period}}$$

$$= \frac{\text{Avg. Inventory}}{\text{COGS / 365}} + \frac{\text{Avg. Accounts Receivable}}{\text{Credit Sales / 365}} - \frac{\text{Avg. Accounts Payable}}{\text{Purchases / 365}}$$

**Derivation**

**Cash flows insufficient.** The term "Cash Conversion Cycle" refers to the time span between a firm's disbursing and collecting cash. However, the CCC cannot be directly observed in cash flows, because these are also influenced by investment and financing activities; it must be derived from Statement of Financial Position data associated with the firm's operations.

**Equation describes retailer.** Although the term "cash conversion cycle" technically applies to a firm in any industry, the equation is generically formulated to apply specifically to a retailer. Since a retailer's operations consist in buying and selling inventory, the equation models the time between

(1) Disbursing cash to satisfy the accounts payable created by purchase of inventory, and

(2) Collecting cash to satisfy the accounts receivable generated by that sale.

**Equation describes a firm that buys & sells on account.** Also, the equation is written to accommodate a firm that *buys and sells on account*. For a *cash-only firm*, the equation would only need data from sales operations (e.g. changes in inventory), because disbursing cash would be directly measurable as *purchase of inventory*, and *collecting cash* would be directly measurable as sale of inventory. However, no such 1:1 correspondence exists for a firm that *buys and sells on account*. Increases and decreases in inventory do not occasion cash flows but accounting vehicles (receivables and payables, respectively); increases and decreases in cash will remove these accounting vehicles (receivables and payables, respectively) from the books. Thus, the CCC must be calculated by tracing a change in cash through its effect upon receivables, inventory, payables, and finally back to cash-thus, the term *cash conversion cycle*, and the observation that these four accounts "articulate" with one another.

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| Label | Transaction | Accounting (use different accounting vehicles if the transactions occur in a different order) |
|---|---|---|
| A | Suppliers (agree to) deliver inventory<br>? Firm owes $X cash (debt) to suppliers | • Operations (increasing inventory by $X)<br>? Create accounting vehicle (increasing accounts payable by $X) |
| B | Customers (agree to) acquire that inventory<br>? Firm is owed $Y cash (credit) from customers | • Operations (decreasing inventory by $Y)<br>? Create accounting vehicle (booking "COGS" expense of $Y; accruing revenue and increasing accounts receivable of $Y) |
| C | Firm disburses $X cash to suppliers<br>? Firm removes its debts to its suppliers | • Cashflows (decreasing cash by $X)<br>? Remove accounting vehicle (decreasing accounts payable by $X) |
| D | Firm collects $Y cash from customers<br>? Firm removes its credit from its | • Cashflows (increasing cash by $Y)<br>? Remove accounting vehicle (decreasing accounts receivable by $Y.) |

Taking these four transactions in pairs, analysts draw attention to five important intervals, referred to as conversion cycles (or conversion periods):

- The **Cash Conversion Cycle** emerges as interval C→D (i.e. *disbursing cash collecting cash*).
- the **payables conversion period** (or "Days payables outstanding") emerges as interval A→C (i.e. *owing cash disbursing cash*)
- the **operating cycle** emerges as interval A→D (i.e. owing cash collecting cash)
- the **inventory conversion period** or "Days inventory outstanding" emerges as interval A→B (i.e. *owing cash being owed cash*)

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- the receivables conversion period (or "Days sales outstanding") emerges as interval B→D (i.e. *being owed cash collecting cash*

Knowledge of any three of these conversion cycles permits derivation of the fourth (leaving aside the *operating cycle*, which is just the sum of the *inventory conversion period* and the *receivables conversion period*.)

Hence,

**interval {C → D} = interval {A → B} + interval {B → D} − interval {A → C}**

$$\text{CCC (in days)} = \underset{\text{period}}{\text{Inventory conversion}} + \underset{\text{period}}{\text{Receivables conversion}} - \underset{\text{period}}{\text{Payables conversion}}$$

In calculating each of these three constituent Conversion Cycles, we use the equation TIME =LEVEL/RATE (since each interval roughly equals the TIME needed for its LEVEL to be achieved at its corresponding RATE).

- We estimate its LEVEL "during the period in question" as the average of its levels in the two balance-sheets that surround the period: (Lt1+Lt2)/2.
- To estimate its RATE, we note that Accounts Receivable grows only when revenue is accrued; and Inventory shrinks and Accounts Payable grows by an amount equal to the COGS expense (in the long run, since COGS actually accrues sometime after the inventory delivery, when the customers acquire it).
- **Payables conversion period:** Rate = [inventory increase + COGS], since these are the items for the period that can increase "trade accounts payables," i.e. the ones that grew its inventory.

NOTICE that we make an exception when calculating this interval: although we use a period average for the LEVEL of inventory, we also consider any increase in inventory as contributing to its RATE of change. This is because the purpose of the CCC is to measure the effects of inventory growth on cash outlays. If inventory grew during the period, we want to know about it.

- **Inventory conversion period:** Rate = COGS, since this is the item that (eventually) shrinks inventory.
- **Receivables conversion period:** Rate = revenue, since this is the item that can grow receivables (sales).

**Note - Cost of goods sold** - Cost of goods sold (COGS) refer to the inventory costs of those goods a business has sold during a particular period. Costs are associated with particular goods using one of several formulas, including specific identification, first-in first-out (FIFO), or average cost. Costs include all costs of purchase, costs of conversion and other costs incurred in bringing the inventories to their present location and condition. Costs of goods made by the business include material, labor, and allocated overhead. The costs of those goods not yet sold are deferred as costs of inventory until the inventory is sold or written down in value.

## 7.6 Distressed inventory

Also known as distressed or expired stock, distressed inventory is inventory whose potential to be sold at a normal cost has passed or will soon pass. In certain industries it could also mean that the stock is or will soon be impossible to sell. Examples of distressed inventory include products that have reached their expiry date, or have reached a date in advance of expiry at which the planned market will no longer purchase them (e.g. 3 months left to expiry), clothing that is defective or out of fashion, music that is no longer popular and old newspapers or magazines. It also includes computer or consumer-electronic equipment that is obsolete or discontin-

ued and whose manufacturer is unable to support it. One current example of distressed inventory is the VHS format.

In 2001, Cisco wrote off inventory worth US $2.25 billion due to duplicate orders. This is one of the biggest inventory write-offs in business history.

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## 7.7 Inventory credit

Inventory credit refers to the use of stock, or inventory, as collateral to raise finance. Where banks may be reluctant to accept traditional collateral, for example in developing countries where land title may be lacking, inventory credit is a potentially important way of overcoming financing constraints. This is not a new concept; archaeological evidence suggests that it was practiced in Ancient Rome. Obtaining finance against stocks of a wide range of products held in a bonded warehouse is common in much of the world. It is, for example, used with Parmesan cheese in Italy. Inventory credit on the basis of stored agricultural produce is widely used in Latin American countries and in some Asian countries. A precondition for such credit is that banks must be confident that the stored product will be available if they need to call on the collateral; this implies the existence of a reliable network of certified warehouses. Banks also face problems in valuing the inventory. The possibility of sudden falls in commodity prices means that they are usually reluctant to lend more than about 60% of the value of the inventory at the time of the loan.

## 7.8 Inventory Investment

**Inventory investment** is a component of gross domestic product (GDP). What is produced in a certain country is naturally also sold eventually, but some of the goods produced in a given year may be sold in a later year rather than in the year they were produced. Conversely, some of the goods sold in a given year might have been produced in an earlier year. The difference between goods produced (production) and goods sold (sales) in a given year is called inventory investment. The term can be applied to the economy as a whole or to an individual firm.

Inventory investment = production - sales

Thus, if production per unit time exceeds sales per unit time, then inventory investment per unit time is positive; as a result, at the end of that period of time the stock of inventories on hand will be greater than it was at the beginning. The reverse is true if production is less than sales.

## 7.9 Intended and Unintended Inventory Investment

A positive flow of **Intended inventory investment** occurs when a firm expects that sales will be high enough that the current level of inventories on hand may be insufficient-perhaps because in the presence of very short-term fluctuations in the timing of customer purchases, there is a risk of temporarily being unable to supply the product when a customer demands it. To avoid that prospect, the firm deliberately builds up its inventories-that is, engages in positive intended inventory investment by deliberately producing more than it expects to sell. Economists view this positive intended inventory investment as a form of spending-in effect, the firm is buying inventories from itself.

Conversely, if a firm decides that its current level of inventories is unjustifiably high-some of the inventories are taking up costly warehouse space while exceeding what is needed to prevent stock-outs-then it will engage in a negative flow of intended inventory investment. It does this by deliberately producing less than what it expects to sell.

Positive or negative **unintended inventory investment** occurs when customers buy a different amount of the firm's product than the firm expected during a particular

time period. If customers buy less than expected, inventories unexpectedly build up and unintended inventory investment turns out to have been positive. If customers buy more than expected, inventories unexpectedly decline and unintended inventory investment turns out to have been negative.

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Either positive or negative intended inventory investment can coincide with either positive or negative unintended inventory investment. They are separate, unrelated events: one is based on deliberate actions to adjust the stock of inventories, while the other results from mispredictions of customer demand.

## 7.10 Inventory Investment over Business cycles

A typical business cycle plays out in the following way. Starting from some point in the business cycle, some group (consumers, government, purchasers of exports, etc.) decides for some reason to have a sustained increase in their spending. This may come as a surprise to producers, who initially experience negative inventory investment as their sales have unexpectedly exceeded their production. Now their inventories are too low, for two reasons: (1) Inventories have accidentally gone down, and (2) the optimal level of inventories-what producers want to have on hand-has gone up because sustained customer demand has gone up and there is increased danger of temporary stock-outs. In order to build inventories up to an appropriate level, firms engage in positive intended inventory investment. This positive flow of intended inventory investment continues until the target level of inventories is reached. During this time, the economy is in a boom both due to the original sustained increase in spending and due to the positive flow of intended inventory investment.

At some point, there is a sustained decline in some type of spending for some reason. (One reason may simply be that, once inventories reach their desired level, there stops being positive intended inventory investment; but there may be other reasons as well.) Then there is positive unintended inventory investment as firms are caught by surprise by the external drop in demand and they fail to simultaneously lower their production. Now inventories are too high, for two reasons: (1) They have accidentally risen, and (2) the optimal level of inventories is lower now due to the new, lower level of sustained demand. So in order to lower their inventories, forms deliberately cut back their production to below the level of demand by their customers, thus causing inventories to be deliberately drawn down-that is, intended inventory investment is negative. Intended inventory investment remains negative until the target level of inventories is reached. During this time, the economy, having peaked out, is in a downturn (a recession) both due to the sustained decrease in non-inventory expenditure and due to the negative flow of intended inventory investment.

At some point, there is a sustained increase in some type of spending for some reason. (One reason may simply be that, once inventories sink to their desired level, there stops being negative intended inventory investment, which goes up from negative to zero; but again there may be other reasons as well.) At this point there is negative unintended inventory investment as firms are caught by surprise by the external increase in demand and they fail to simultaneously raise their production. Now inventories are too low, again for two reasons, and we are back where we started in the cycle. The recession has bottomed out, sustained spending is once again high, target inventory levels are higher than actual inventory levels, and intended inventory investment is positive.

## 7.11 Inventory Management Software's

Inventory management software is a computer-based system for tracking product levels, orders, sales and deliveries. It can also be used in the manufacturing industry to create a work order, bill of materials and other production-related documents.

Company's use inventory management software to avoid product overstock and outages. It is a tool for organizing inventory data that before was generally stored in hard-copy form or in Microsoft Excel spreadsheets.

### Components

Inventory management software is made up of several components, all working together to create a cohesive inventory and stocks for many organizations control systems. These components include (in alphabetical order):

### Asset tracking

When a product is in a warehouse or store, it can be tracked via its bar code and/or other tracking criteria, such as serial number, lot number or revision number.

### Barcoding

Barcodes are the means whereby data on products and orders is inputted into inventory management software. A barcode reader is required to read barcodes and look up information on the products they represent.

### Order management

Once products reach a certain low level, a company's inventory management system can be programmed to tell managers to reorder that product. This helps companies avoid running out of products or tying up too much capital in inventory.

### Service management

Companies that are primarily service-oriented rather than product-oriented can use inventory management software to track the cost of the materials they use to provide services, such as cleaning supplies. This way, they can attach prices to their services that reflect the total cost of performing them.

## 7.12 History

The Universal Product Code (UPC) was adopted by the grocery industry in April 1973 as the standard barcode for all grocers, though it was not introduced at retailing locations until 1974. This helped drive down costs for inventory management because retailers in the United States and Canada didn't have to purchase multiple barcode-readers to scan competing barcodes. There was now one primary barcode for grocers and other retailers to buy one type of reader for.

In the early 1980s, PCs debuted and started becoming popular. This further pushed down the cost of barcodes and readers. It also allowed the first versions of inventory management software to be put into place. One of the biggest hurdles in selling readers and barcodes to retailers was the fact that they didn't have a place to store the information they scanned. As computers became more common and affordable, this hurdle was overcome. Once barcodes and inventory management programs started spreading through grocery stores, inventory management by hand became less practical. Writing inventory data by hand on paper was replaced by scanning products and inputting information into a computer by hand.

Starting in the early 2000s, inventory management software progressed to the point where businesspeople no longer needed to input data by hand but could instantly update their database with barcode readers.

## 7.13 Purpose

Companies often use inventory management software to reduce their carrying costs. The software is used to track products and parts as they are transported from a vendor to a warehouse, between warehouses, and finally to a retail location or directly to a customer.

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Inventory management software is used for a variety of purposes, including:

- Maintaining a balance between too much and too little inventory.
- Tracking inventory as it is transported between locations.
- Receiving items into a warehouse or other location.
- Picking, packing and shipping items from a warehouse.
- Keeping track of product sales and inventory levels.
- Cutting down on product obsolescence and spoilage.

## 7.14 Manufacturing uses/applications

Manufacturers mainly use inventory management software to create work orders and bills of materials. This facilitates the manufacturing process by helping manufacturers efficiently assemble the tools and parts they need to perform specific tasks. For more-complex manufacturing jobs, manufacturers can create multilevel work orders and bills of materials, which have a timeline of processes that need to, happen in the proper order to build a final product. Other work orders that can be created using inventory management software include reverse work orders and auto work orders. Manufacturers also use inventory management software for tracking assets, receiving new inventory and additional tasks businesses in other industries use it for.

### Advantages

There are several advantages to using inventory management software in a business setting.

### Cost savings

In many cases, a company's inventory represents one of its largest investments, along with its workforce and locations. Inventory management software helps companies cut expenses by minimizing the amount of unnecessary parts and products in storage. It also helps companies keep lost sales to a minimum by having enough stock on hand to meet demand.

### Warehouse organization

Inventory management software can help distributors, wholesalers, manufacturers and retailers optimize their warehouses. If certain products are often sold together or are more popular than others, those products can be grouped together or placed near the delivery area to speed up the process of picking, packing and shipping to customers.

### Updated data

Up-to-date data on inventory conditions and levels is also advantage inventory management software gives companies. Company executives can usually access the software through a mobile device, laptop or PC to check current inventory numbers.

### Time savings

With the aid of restricted user rights, company managers can allow many employees to assist in inventory management. They can grant employees enough information access to receive products, make orders, transfer products and do other tasks without compromising company security. This can speed up the inventory-management process and save managers' time.

### Disadvantages

The main disadvantages of inventory management software are its cost and complexity.

*Check Your Progress*

iv. What is barcoding?

v. What is distressed inventory?

## Expense

Cost can be a major disadvantage of inventory management software. Many large companies use inventory management software, but small businesses can find it difficult to afford it. Barcode readers and other hardware can compound this problem by adding even more cost to companies. The advantage of allowing multiple employees to perform inventory-management tasks is tempered by the cost of additional barcode readers.

## Complexity

Inventory management software is not necessarily simple or easy to learn. A company's management team must dedicate a certain amount of time to learning a new system, including its software and hardware, in order to put it to use. Most inventory management software includes training manuals and other information available to users. Despite its apparent complexity, inventory management software offers a degree of stability to companies. For example, if an IT employee in charge of the system leaves the company, a replacement can be comparatively inexpensive to train compared to if the company used multiple programs to store inventory data.

### CASE STUDY - Quality Issues in inventory control

Your business's basic stock should provide a reasonable assortment of products and should be big enough to cover the normal sales demands of your business. If you're a start-up, you won't have actual sales and stocking figures from previous years to guide you, you must project your first year's sales based on your business plan.

When calculating basic stock, you must also factor in lead time-the length of time between reordering and receiving a product. For instance, if your lead time is four weeks and a particular product line sells 10 units a week, then you must reorder before the basic inventory level falls below 40 units. If you do not reorder until you actually need the stock, you'll have to wait four weeks without the product.

Insufficient inventory means lost sales and costly, time-consuming back orders. Running out of raw materials or parts that are crucial to your production process means increased operating costs, too. Your employees will be getting paid to sit around because there's no work for them to do; when the inventory does come in, they'll be paid for working overtime to make up for lost production time. In some situations, you could even end up buying emergency inventory at high prices.

One way to protect yourself from such shortfalls is by building a safety margin into basic inventory figures. To figure out the right safety margin for your business, try to think of all the outside factors that could contribute to delays, such as suppliers who tend to be late or goods being shipped in from overseas. Once you have been in business a while, you'll have a better "feel" for delivery times and will find it fairly easy to calculate your safety margin.

### Avoiding Excess Inventory

Avoiding excess inventory is especially important for owners of companies with seasonal product lines, such as clothing, home accessories or holiday and gift items. These products have a short shelf life and are hard to sell once they are no longer in fashion. Entrepreneurs who sell more timeless products, such as plumbing equipment, office supplies or auto products, have more leeway because it takes longer for these items to become obsolete.

No matter what your business, however, excess inventory is something to be avoided. It costs you money in extra overhead, debt service on loans to purchase the excess inventory, additional personal property tax on unsold inventory and increased insurance costs. In fact, one merchandise consultant estimates that it costs the average retailer anywhere from 20 percent to 30 percent of the original inventory investment

just to maintain it. Buying excess inventory also reduces your liquidity-something to be avoided. Consider the example of an auto supply retailer who finds himself with the opportunity to buy 1,000 gallons of antifreeze at a huge discount. If he buys the antifreeze and it turns out to be a mild winter, he'll be sitting on 1,000 gallons of antifreeze. Even though he knows he can sell the antifreeze during the next cold winter, it's still taking up space in his warehouse for an entire year-space that could be devoted to more profitable products.

When you find yourself with excess inventory, your natural reaction will probably be to reduce the price and sell it quickly. Although this solves the overstocking problem, it also reduces your return on investment. All your financial projections assume that you will receive the full price for your goods. If you slash your prices by 15 percent to 25 percent just to get rid of the excess inventory, you're losing money you had counted on in your business plan.

Other novice entrepreneurs will react to excess inventory by being overly cautious the next time they order stock. However, this puts you at risk of having an inventory shortage and continuing a costly cycle of errors. To avoid accumulating excess inventory, establish a realistic safety margin and order only what you're sure you can sell.

## 7.15 SUMMARY

Inventory is the total amount of goods and/or materials contained in a store or factory at any given time. Store owners need to know the precise number of items on their shelves and storage areas in order to place orders or control losses. Factory managers need to know how many units of their products are available for customer orders. Restaurants need to order more food based on their current supplies and menu needs. All of these businesses rely on an inventory count to provide answers.

The word 'inventory' can refer to both the total amount of goods and the act of counting them. Many companies take an inventory of their supplies on a regular basis in order to avoid running out of popular items. Others take an inventory to insure the number of items ordered matches the actual number of items counted physically. Shortages or overages after an inventory can indicate a problem with theft (called 'shrinkage' in retail circles) or inaccurate accounting practices.

## ANSWERS TO 'CHECK YOUR PROGRESS'

(i) Inventory management is the process of efficiently overseeing the constant flow of units into and out of an existing inventory.

(ii) Inventory credit refers to the use of stock, or inventory, as collateral to raise finance. Where banks may be reluctant to accept traditional collateral, for example in developing countries where land title may be lacking, inventory credit is a potentially important way of overcoming financing constraints.

(iii) Inventory investment is a component of gross domestic product (GDP).

Inventory investment = production - sales

(iv) Barcodes are the means whereby data on products and orders is inputted into inventory management software. A barcode reader is required to read barcodes and look up information on the products they represent.

(v) Also known as distressed or expired stock, distressed inventory is inventory whose potential to be sold at a normal cost has passed or will soon pass.

## 7.16 TEST YOURSELF

1. Define the term Inventory. What do you mean by Inventory Management?
2. Name the two basic types of Inventories commonly studies.

NOTES

3. What are the various reasons because of which companies pay so much importance on maintaining their Inventories?
4. Explain the concept of Inventory proportionality.
5. What are the various uses of Inventory Management Software's?
6. Write short notes on - FIFO, Cost of goods sold.

## 7.17 REFERENCES


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## 7.18 FURTHER READING

- *Production and Material Management: Cundiff and Govani*

# 8 TOTAL QUALITY MANAGEMENT

*The Chapter Covers :*



*Learning Objectives:*

After going through this chapter, you should be able to

- Explain TQM
- Define SQC
- Clarify Control System
- Explain Six Sigma
- Discuss Descriptive Statistics

## 8.1 INTRODUCTION

NOTES

Total quality management or TQM is an integrative philosophy of management for continuously improving the quality of products and processes.

TQM functions on the premise that the quality of products and processes is the responsibility of everyone who is involved with the creation or consumption of the products or services offered by an organization. In other words, TQM capitalizes on the involvement of management, workforce, suppliers, and even customers, in order to meet or exceed customer expectations. Considering the practices of TQM as discussed in six empirical studies, Cua, McKone, and Schroeder (2001) identified the nine common TQM practices as cross-functional product design, process management, supplier quality management, customer involvement, information and feedback, committed leadership, strategic planning, cross-functional training, and employee involvement.

## 8.2 The Eight Elements of TQM

Eight elements are key in ensuring the success of TQM in an organization.

Total Quality Management is a management approach that originated in the 1950?s and has steadily become more popular since the early 1980?s. Total Quality is a description of the culture, attitude and organization of a company that strives to provide customers with products and services that satisfy their needs. The culture requires quality in all aspects of the company's operations, with processes being done right the first time and defects and waste eradicated from operations.

To be successful implementing TQM, an organization must concentrate on the eight key elements:

1. Ethics
2. Integrity
3. Trust
4. Training
5. Teamwork
6. Leadership
7. Recognition
8. Communication


This paper is meant to describe the eight elements comprising TQM.

**Key Elements**

TQM has been coined to describe a philosophy that makes quality the driving force behind leadership, design, planning, and improvement initiatives. For this, TQM requires the help of those eight key elements. These elements can be divided into four groups according to their function. The groups are:

I. Foundation - It includes: Ethics, Integrity and Trust.

II. Building Bricks - It includes: Training, Teamwork and Leadership.

III. Binding Mortar - It includes: Communication.

IV. Roof - It includes: Recognition.

**Foundation**

TQM is built on a foundation of ethics, integrity and trust. It fosters openness, fairness and sincerity and allows involvement by everyone. This is the key to unlocking the ultimate potential of TQM. These three elements move together, however, each element offers something different to the TQM concept.

NOTES

1. **Ethics** - Ethics is the discipline concerned with good and bad in any situation. It is a two-faceted subject represented by organizational and individual ethics. Organizational ethics establish a business code of ethics that outlines guidelines that all employees are to adhere to in the performance of their work. Individual ethics include personal rights or wrongs.

2. **Integrity** - Integrity implies honesty, morals, values, fairness, and adherence to the facts and sincerity. The characteristic is what customers (internal or external) expect and deserve to receive. People see the opposite of integrity as duplicity. TQM will not work in an atmosphere of duplicity.

3. **Trust** - Trust is a by-product of integrity and ethical conduct. Without trust, the framework of TQM cannot be built. Trust fosters full participation of all members. It allows empowerment that encourages pride ownership and it encourages commitment. It allows decision making at appropriate levels in the organization, fosters individual risk-taking for continuous improvement and helps to ensure that measurements focus on improvement of process and are not used to contend people. Trust is essential to ensure customer satisfaction. So, trust builds the cooperative environment essential for TQM.

8.3 **Bricks** Aasing on the strong foundation of trust, ethics and integrity, bricks are placed to reach the roof of recognition. It includes:

4. **Training** - Training is very important for employees to be highly productive. Supervisors are solely responsible for implementing TQM within their departments, and teaching their employees the philosophies of TQM. Training that employees require are interpersonal skills, the ability to function within teams, problem solving, decision making, job management performance analysis and improvement, business economics and technical skills. During the creation and formation of TQM, employees are trained so that they can become effective employees for the company.

5. **Teamwork** - To become successful in business, teamwork is also a key element of TQM. With the use of teams, the business will receive quicker and better solutions to problems. Teams also provide more permanent improvements in processes and operations. In teams, people feel more comfortable bringing up problems that may occur, and can get help from other workers to find a solution and put into place. There are mainly three types of teams that TQM organizations adopt:

   A. **Quality Improvement Teams or Excellence Teams (QITS)** - These are temporary teams with the purpose of dealing with specific problems that often re-occur. These teams are set up for period of three to twelve months.

   B. **Problem Solving Teams (PSTs)** - These are temporary teams to solve certain problems and also to identify and overcome causes of problems. They generally last from one week to three months.

C. Natural Work Teams (NWTs) - These teams consist of small groups of skilled workers who share tasks and responsibilities. These teams use concepts such as employee involvement teams, self-managing teams and quality circles. These teams generally work for one to two hours a week.

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6. **Leadership** - It is possibly the most important element in TQM. It appears everywhere in organization. Leadership in TQM requires the manager to provide an inspiring vision, make strategic directions that are understood by all and to instill values that guide subordinates. For TQM to be successful in the business, the supervisor must be committed in leading his employees. A supervisor must understand TQM, believe in it and then demonstrate their belief and commitment through their daily practices of TQM. The supervisor makes sure that strategies, philosophies, values and goals are transmitted down through out the organization to provide focus, clarity and direction. A key point is that TQM has to be introduced and led by top management. Commitment and personal involvement is required from top management in creating and deploying clear quality values and goals consistent with the objectives of the company and in creating and deploying well defined systems, methods and performance measures for achieving those goals.

## 8.4 Binding Mortar

7. **Communication** - It binds everything together. Starting from foundation to roof of the TQM house, everything is bound by strong mortar of communication. It acts as a vital link between all elements of TQM. Communication means a common understanding of ideas between the sender and the receiver. The success of TQM demands communication with and among all the organization members, suppliers and customers. Supervisors must keep open airways where employees can send and receive information about the TQM process. Communication coupled with the sharing of correct information is vital. For communication to be credible the message must be clear and receiver must interpret in the way the sender intended.

   There are different ways of communication such as:

   A. **Downward communication** - This is the dominant form of communication in an organization. Presentations and discussions basically do it. By this the supervisors are able to make the employees clear about TQM.

   B. **Upward communication** - By this the lower level of employees are able to provide suggestions to upper management of the affects of TQM. As employees provide insight and constructive criticism, supervisors must listen effectively to correct the situation that comes about through the use of TQM. This forms a level of trust between supervisors and employees. This is also similar to empowering communication, where supervisors keep open ears and listen to others.

   C. **Sideways communication** - This type of communication is important because it breaks down barriers between departments. It also allows dealing with customers and suppliers in a more professional manner.

## 8.5 Roof

8. **Recognition** -

   Recognition is the last and final element in the entire system. It should be provided for both suggestions and achievements for teams as well as indi-

viduals. Employees strive to receive recognition for themselves and their teams. Detecting and recognizing contributors is the most important job of a supervisor. As people are recognized, there can be huge changes in self-esteem, productivity, quality and the amount of effort exhorted to the task at hand. Recognition comes in its best form when it is immediately following an action that an employee has performed. Recognition comes in different ways, places and time such as,

- **Ways** - It can be by way of personal letter from top management. Also by award banquets, plaques, trophies etc.
- **Places** - Good performers can be recognized in front of departments, on performance boards and also in front of top management.
- **Time** - Recognition can given at any time like in staff meeting, annual award banquets, etc.

## 8.6 Principles of TQM

TQM can be defined as the management of initiatives and procedures that are aimed at achieving the delivery of quality products and services. A number of key principles can be identified in defining TQM, including:

- **Executive Management** -

  Top management should act as the main driver for TQM and create an environment that ensures its success.

- **Training** -

  Employees should receive regular training on the methods and concepts of quality.

- **Customer Focus** -

  Improvements in quality should improve customer satisfaction.

- **Decision Making** -

  Quality decisions should be made based on measurements.

- **Methodology and Tools** -

  Use of appropriate methodology and tools ensures that non-conformances are identified, measured and responded to consistently.

- **Continuous Improvement** -

  Companies should continuously work towards improving manufacturing and quality procedures.

- **Company Culture** - The culture of the company should aim at developing employees ability to work together to improve quality.
- **Employee Involvement** - Employees should be encouraged to be pro-active in identifying and addressing quality related problems.

## 8.7 The Cost of TQM

Many companies believe that the costs of the introduction of TQM are far greater than the benefits it will produce. However research across a number of industries has

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costs involved in doing nothing, i.e. the direct and indirect costs of quality problems, are far greater than the costs of implementing TQM.

The American quality expert, Phil Crosby, wrote that many companies chose to pay for the poor quality in what he referred to as the "Price of Nonconformance". The costs are identified in the Prevention, Appraisal, Failure (PAF) Model.

Prevention costs are associated with the design, implementation and maintenance of the TQM system. They are planned and incurred before actual operation, and can include:

- Product Requirements - The setting specifications for incoming materials, processes, finished products/services.
- Quality Planning - Creation of plans for quality, reliability, operational, production and inspections.
- Quality Assurance - The creation and maintenance of the quality system.
- Training - The development, preparation and maintenance of processes.

Appraisal costs are associated with the vendors and customers evaluation of purchased materials and services to ensure they are within specification. They can include:

- Verification - Inspection of incoming material against agreed upon specifications.
- Quality Audits - Check that the quality system is functioning correctly.
- Vendor Evaluation - Assessment and approval of vendors.

Failure costs can be split into those resulting from internal and external failure. Internal failure costs occur when results fail to reach quality standards and are detected before they are shipped to the customer. These can include:

- Waste - Unnecessary work or holding stocks as a result of errors, poor organization or communication.
- Scrap - Defective product or material that cannot be repaired, used or sold.
- Rework - Correction of defective material or errors.
- Failure Analysis - This is required to establish the causes of internal product failure.

External failure costs occur when the products or services fail to reach quality standards, but are not detected until after the customer receives the item. These can include:

- Repairs - Servicing of returned products or at the customer site.
- Warranty Claims - Items are replaced or services re-performed under warranty.
- Complaints - All work and costs associated with dealing with customer's complaints.
- Returns - Transportation, investigation and handling of returned items.

## 8.8 Statistical Quality Control

NOTES

Statistical quality control (SQC) is the term used to describe the set of statistical tools used by quality professionals. Statistical quality control can be divided into three broad categories:

1. **Descriptive statistics** are used to describe quality characteristics and relationships. Included are statistics such as the mean, standard deviation, the range, and a measure of the distribution of data.
2. **Statistical process control** (SPC) involves inspecting a random sample of the output from a process and deciding whether the process is producing products with characteristics that fall within a predetermined range. SPC answers the question of whether the process is functioning properly or not.
3. **Acceptance sampling** is the process of randomly inspecting a sample of goods and deciding whether to accept the entire lot based on the results. Acceptance sampling determines whether a batch of goods should be accepted or rejected.

The tools in each of these categories provide different types of information for use in analyzing quality. Descriptive statistics are used to describe certain quality characteristics, such as the central tendency and variability of observed data. Although descriptions of certain characteristics are helpful, they are not enough to help us evaluate whether there is a problem with quality. Acceptance sampling can help us do this. Acceptance sampling helps us decide whether desirable quality has been achieved for a batch of products, and whether to accept or reject the items produced. Although this information is helpful in making the quality acceptance decision *after* the product has been produced, it does not help us identify and catch a quality problem *during* the production process. For this we need tools in the statistical process control (SPC) category.

All three of these statistical quality control categories are helpful in measuring and evaluating the quality of products or services. However, statistical process control (SPC) tools are used most frequently because they identify quality problems during the production process. For this reason, we will devote most of the chapter to this category of tools. The quality control tools we will be learning about do not only measure the value of a quality characteristic. They also help us identify a *change* or variation in some quality characteristic of the product or process. We will first see what types of variation we can observe when measuring quality. Then we will be able to identify specific tools used for measuring this variation.

## 8.9 Descriptive Statistics

Descriptive statistics is the discipline of quantitatively describing the main features of a collection of data. Descriptive statistics are distinguished from inferential statistics (or inductive statistics), in that descriptive statistics aim to summarize a data set, rather than use the data to learn about the population that the data are thought to represent. This generally means that descriptive statistics, unlike inferential statistics, are not developed on the basis of probability theory. Even when a data analysis draws its main conclusions using inferential statistics, descriptive statistics are generally also presented. For example in a paper reporting on a study involving human subjects, there typically appears a table giving the overall sample size, sample sizes in important subgroups (e.g., for each treatment or exposure group), and demographic or clinical characteristics such as the average age, the proportion of subjects of each sex, and the proportion of subjects with related commodities.

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## Use in statistical analysis

Descriptive statistics provide simple summaries about the sample and the measures. Together with simple graphics analysis, they form the basis of quantitative analysis of data.

Descriptive statistics summarize data. For example, the shooting percentage in basketball is a descriptive statistic that summarizes the performance of a player or a team. This number is the number of shots made divided by the number of shots taken. A player who shoots 33% is making approximately one shot in every three. One making 25% is hitting once in four. The percentage summarizes or describes multiple discrete events. Or, consider the scourge of many students, the grade point average. This single number describes the general performance of a student across the range of their course experiences.

Describing a large set of observations with a single indicator risks distorting the original data or losing important detail. For example, the shooting percentage doesn't tell you whether the shots are three-pointers or lay-ups, and GPA doesn't tell you whether the student was in difficult or easy courses. Despite these limitations, descriptive statistics provide a powerful summary that may enable comparisons across people or other units.

### Univariate analysis

Univariate analysis involves the examination across cases of a single variable, focusing on three characteristics: the distribution; the central tendency; and the dispersion. It is common to compute all three for each study variable.

### Distribution

The distribution is a summary of the frequency of individual or ranges of values for a variable. The simplest distribution would list every value of a variable and the number of cases who had that value. For instance, computing the distribution of gender in the study population means computing the percentages that are male and female. The gender variable has only two, making it possible and meaningful to list each one. However, this does not work for a variable such as income that has many possible values. Typically, specific values are not particularly meaningful (income of 50,000 is typically not meaningfully different from 51,000). Grouping the raw scores using ranges of values reduces the number of categories to something more meaningful. For instance, we might group incomes into ranges of 0-10,000, 10,001-30,000, etc.

Frequency distributions are depicted as a table or as a graph.

### Central tendency

The central tendency of a distribution locates the "center" of a distribution of values. The three major types of estimates of central tendency are the mean, the median, and the mode.

The mean is the most commonly used method of describing central tendency. To compute the mean, take the sum of the values and divide by the count. For example, the mean exam score is determined by summing all the scores and dividing by the number of students taking the exam. For example, consider the test score values:

15, 20, 21, 36, 15, 25, 15

The sum of these 7 values is 147, so the mean is 147/7 =21.

NOTES

The median is the score found at the middle of the set of values, i.e., that has as many cases with a larger value as have a smaller value. One way to compute the median is to sort the values in numerical order, and then locate the value in the middle of the list. For example, if there are 500 values, the median is the average of the two values in 250th and 251st positions. If there are 499 values, the value in 250th position is the median. Sorting the 7 scores above produces:

15, 15, 15, 20, 21, 25, 36

There are 7 scores and score #4 represents the halfway point. The median is 20. If there is an even number of observations, then the median is the mean of the two middle scores. In the example, if there were an 8th observation, with a value of 25, the median becomes the average of the 4th and 5th scores, in this case 20.5.

The mode is the most frequently occurring value in the set. To determine the mode, compute the distribution as above. The mode is the value with the greatest frequency. In the example, the modal value 15 occurs three times. In some distributions there is a "tie" for the highest frequency, i.e., there are multiple modal values. These are called multi-modal distributions.

Notice that the three measures typically produce different results. The term "average" obscures the difference between them and is better avoided. The three values are equal if the distribution is unimodal and symmetric (e.g. like the bell-shaped normal distribution).

## Dispersion

Dispersion is the spread of values around the central tendency. There are two common measures of dispersion, the range and the standard deviation. The range is simply the highest value minus the lowest value. In our example distribution, the high value is 36 and the low is 15, so the range is 36 – 15 = 21.

The standard deviation is a more accurate and detailed estimate of dispersion because an outlier can greatly exaggerate the range (as was true in this example where the single outlier value of 36 stands apart from the rest of the values). The standard deviation shows the relation that set of scores has to the mean of the sample. Again let's take the set of scores:

15, 20, 21, 36, 15, 25, 15

to compute the standard deviation, we first find the distance between each value and the mean. We know from above that the mean is 21. So, the differences from the mean are:

15 – 21 = –6

20 – 21 = –1

21 – 21 = 0

36 – 21 = 15

15 – 21 = –6

25 – 21 = +4

15 – 21 = –6

*Check Your Progress*

i. What is total quality management?

ii. What do you mean by SQC?

NOTES

Notice that values that are below the mean have negative differences and values above it have positive ones. Next, we square each difference:

$(-6)^2 = 36$

$(-1)^2 = 1$

$(+0)^2 = 0$

$(15)^2 = 225$

$(-6)^2 = 36$

$(+4)^2 = 16$

$(-6)^2 = 36$

Now, we take these "squares" and sum them to get the sum of squares (SS) value. Here, the sum is 350. Next, we divide this sum by the number of scores minus 1. Here, the result is 350 / 6 = 58.3. This value is known as the variance. To get the standard deviation, we take the square root of the variance (remember that we squared the deviations earlier). This would be ?58.3 = 7.63.

Although this computation may seem convoluted, it's actually quite simple. In English, we can describe the standard deviation as:

"the square root of the sum of the squared deviations from the mean divided by the number of scores minus one"

The standard deviation allows us to reach some conclusions about specific scores in our distribution. Assuming that the distribution of scores is close to "normal", the following conclusions can be reached:

- approximately 68% of the scores in the sample fall within one standard deviation of the mean
- approximately 95% of the scores in the sample fall within two standard deviations of the mean
- approximately 99% of the scores in the sample fall within three standard deviations of the mean

For instance, since the mean in our example is 21 and the standard deviation is 7.63, we can from the above statement estimate that approximately 95% of the scores will fall in the range of 21 ? (2×7.63) to 21 + (2×7.63) or between 5.74 and 36.26. Values beyond two standard deviations from the mean can be considered "outliers". 36 is the only such value in our distribution. Outliers help identify observations for further analysis or possible problems in the observations. Standard deviations also convert measures on very different scales, such as height and weight, into values that can be compared.

## Other statistics

In research involving comparisons between groups, emphasis is often placed on the significance level for the hypothesis that the groups being compared differ to a degree greater than would be expected by chance. This significance level is often represented as a p-value, or sometimes as the standard score of a test statistic. In contrast, an effect size conveys the estimated magnitude and direction of the difference between groups, without regard to whether the difference is statistically significant. Reporting

significance levels without effect sizes is problematic, since for large sample sizes even small effects of little practical importance can be statistically significant.

### Examples of descriptive statistics

Most statistics can be used either as a descriptive statistic, or in an inductive analysis. For example, we can report the average reading test score for the students in each classroom in a school, to give a descriptive sense of the typical scores and their variation. If we perform a formal hypothesis test on the scores, we are doing inductive rather than descriptive analysis.

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## Statistical Process Control

Statistical process control (SPC) is the application of statistical methods to the monitoring and control of a process to ensure that it operates at its full potential to produce conforming product. Under SPC, a process behaves predictably to produce as much conforming product as possible with the least possible waste. While SPC has been applied most frequently to controlling manufacturing lines, it applies equally well to any process with a measurable output. Key tools in SPC are control charts, a focus on improvement and designed experiments.

Much of the power of SPC lies in the ability to examine a process and the sources of variation in that process using tools that give weight to objective analysis over subjective opinions and that allow the strength of each source to be determined numerically. Variations in the process that may affect the quality of the end product or service can be detected and corrected, thus reducing waste as well as the likelihood that problems will be passed on to the customer. With its emphasis on early detection and prevention of problems, SPC has a distinct advantage over other quality methods, such as inspection, that apply resources to detecting and correcting problems after they have occurred.

In addition to reducing waste, SPC can lead to a reduction in the time required to produce the product or service from end to end. This is partially due to a diminished likelihood that the final product will have to be reworked, but it may also result from using SPC data to identify bottlenecks, wait times, and other sources of delays within the process. Process cycle time reductions coupled with improvements in yield have made SPC a valuable tool from both a cost reduction and a customer satisfaction standpoint.

### History

Statistical process control was pioneered by Walter A. Shewart in the early 1920s. W. Edwards Deming later applied SPC methods in the United States during World War II, thereby successfully improving quality in the manufacture of munitions and other strategically important products. Deming was also instrumental in introducing SPC methods to Japanese industry after the war had ended.

Shewhart created the basis for the control chart and the concept of a state of statistical control by carefully designed experiments. While Dr. Shewhart drew from pure mathematical statistical theories, he understood that data from physical processes seldom produces a "normal distribution curve" (a Gaussian distribution, also commonly referred to as a "bell curve"). He discovered that observed variation in manufacturing data did not always behave the same way as data in nature (for example, Brownian motion of particles). Dr. Shewhart concluded that while every process

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displays variation, some processes display controlled variation that is natural to the process (common causes of variation), while others display uncontrolled variation that is not present in the process causal system at all times (special causes of variation).

In 1988, the Software Engineering Institute introduced the notion that SPC can be usefully applied to non-manufacturing processes, such as software engineering processes, in the Capability Maturity Model (CMM). This idea exists today within the Level 4 and Level 5 practices of the Capability Maturity Model Integration (CMMI). This notion that SPC is a useful tool when applied to non-repetitive, knowledge-intensive processes such as engineering processes has encountered much skepticism, and remains controversial today.

## General

In mass-manufacturing, the quality of the finished article was traditionally achieved through post-manufacturing inspection of the product; accepting or rejecting each article (or samples from a production lot) based on how well it met its design specifications. In contrast, Statistical Process Control uses statistical tools to observe the performance of the production process in order to predict significant deviations that may later result in rejected product.

A main concept is that, for any measurable process characteristic, the notion that causes of variation can be separated into two distinct classes: 1) Normal (sometimes also referred to as common or chance) causes of variation and 2) assignable (sometimes also referred to as special) causes of variation. The idea is that most processes have many causes of variation, most of them are minor, can be ignored, and if we can only identify the few dominant causes, then we can focus our resources on those. SPC allows us to detect when the few dominant causes of variation are present. If the dominant (assignable) causes of variation can be detected, potentially they can be identified and removed. Once removed, the process is said to be stable, which means that its resulting variation can be expected to stay within a known set of limits, at least until another assignable cause of variation is introduced.

For example, a breakfast cereal packaging line may be designed to fill each cereal box with 500 grams of product, but some boxes will have slightly more than 500 grams, and some will have slightly less, in accordance with a distribution of net weights. If the production process, its inputs, or its environment changes (for example, the machines doing the manufacture begin to wear) this distribution can change. For example, as its cams and pulleys wear out, the cereal filling machine may start putting more cereal into each box than specified. If this change is allowed to continue unchecked, more and more product will be produced that fall outside the tolerances of the manufacturer or consumer, resulting in waste. While in this case, the waste is in the form of "free" product for the consumer, typically waste consists of rework or scrap.

By observing at the right time what happened in the process that led to a change, the quality engineer or any member of the team responsible for the production line can troubleshoot the root cause of the variation that has crept in to the process and correct the problem.

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## How to use SPC

Statistical Process Control may be broadly broken down into three sets of activities: understanding the process, understanding the causes of variation, and elimination of the sources of special cause variation.

In understanding a process, the process is typically mapped out and the process is monitored using control charts. Control charts are used to identify variation that may be due to special causes, and to free the user from concern over variation due to common causes. This is a continuous, ongoing activity. When a process is stable and does not trigger any of the detection rules for a control chart, a process capability analysis may also be performed to predict the ability of the current process to produce conforming (i.e. within specification) product in the future.

When excessive variation is identified by the control chart detection rules, or the process capability is found lacking, additional effort is exerted to determine causes of that variance. The tools used include Ishikawa diagrams, designed experiments and Pareto charts. Designed experiments are critical to this phase of SPC, as they are the only means of objectively quantifying the relative importance of the many potential causes of variation.

Once the causes of variation have been quantified, effort is spent in eliminating those causes that are both statistically and practically significant (i.e. a cause that has only a small but statistically significant effect may not be considered cost-effective to fix; however, a cause that is not statistically significant can never be considered practically significant). Generally, this includes development of standard work, error-proofing and training. Additional process changes may be required to reduce variation or align the process with the desired target, especially if there is a problem with process capability.

For digital SPC charts, so-called SPC rules usually come with some rule specific logic that determines a 'derived value' that is to be used as the basis for some (setting) correction. One example of such a derived value would be (for the common N numbers in a row ranging up or down 'rule'): derived value = last value + average difference between the last N numbers (which would, in effect, be extending the row to be expected next value).

Most SPC charts work best for numeric data with Gaussian assumptions. Recently a new control chart: The real-time contrasts chart was proposed to handle process data with complex characteristics, e.g. high-dimensional, mix numerical and categorical, missing-valued, non-Gaussian, non-linear relationship.

## Acceptance Sampling

Acceptance sampling uses statistical sampling to determine whether to accept or reject a production lot of material. It has been a common quality control technique used in industry and particularly the military for contracts and procurement. It is usually done as products leave the factory, or in some cases even within the factory. Most often a producer supplies a consumer a number of items and decision to accept or reject the lot is made by determining the number of defective items in a sample from the lot. The lot is accepted if the number of defects falls below where the acceptance number or otherwise the lot is rejected.

A wide variety of acceptance sampling plans are available.

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### History

Acceptance sampling procedures became common during WWII. Sampling plans, such as MIL-STD-105, were developed by Harold F. Dodge and others and became frequently used as standards.

More recently, quality assurance broadened the scope beyond final inspection to include all aspects of manufacturing. Broader quality management systems include methodologies such as statistical process control, HACCP, six sigma, and ISO 9000. Some use of acceptance sampling still remains.

### Rationale

Sampling provides one rational means of verification that a production lot conforms with the requirements of technical specifications. 100% inspection does not guarantee 100% compliance and is too time consuming and costly. Rather than evaluating all items, a specified sample is taken, inspected or tested, and a decision is made about accepting or rejecting the entire production lot.

Plans have known risks: an acceptable quality limit (AQL) and a reject able quality level (LTDP) is part of the operating characteristic curve of the sampling plan. These are primarily statistical risks and do not necessarily imply that defective product is intentionally being made or accepted. Plans can have a known average outgoing quality limit (AOQL).

## 8.10 Acceptance sampling for attributes

A single sampling plan for attributes is a statistical method by which the lot is accepted or rejected on the basis of one sample. Suppose that we have a lot of size $M$ ; a random sample of size $N < M$ is selected from the lot; and an acceptance number $B$ is determined. If it is found the number of nonconforming is less than or equal to $B$, the lot is accepted; and if the number of nonconforming is greater than $B$, the lot is not accepted. The design of a single sampling plan requires the selection of the sample size $N$ and the acceptance number $B$.

MIL-STD-105 was a United States defense standard that provided procedures and tables for sampling by attributes (pass or fail characteristic). MIL-STD-105E was cancelled in 1995 but is available in related documents such as ANSI/ASQ Z1.4, "Sampling Procedures and Tables for Inspection by Attributes". Several levels of inspection are provided and can be indexed to several AQLs. The sample size is specified and the basis for acceptance or rejection (number of defects) is provided.

### Variables plans

When a measured characteristic produces a number, other sampling plans such as those based on MIL-STD-414 are often used. Compared with attribute sampling plans, these often use a smaller sample size for the same indexed AQL.

### Process Control

Process control is extensively used in industry and enables mass production of continuous processes such as oil refining, paper manufacturing, chemicals, power plants and many other industries. Process control enables automation, with which a small staff of operating personnel can operate a complex process from a central control room.

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For example, heating up the temperature in a room is a process that has the specific, desired outcome to reach and maintain a defined temperature (e.g. 20°C), kept constant over time. Here, the temperature is the **controlled variable**. At the same time, it is the **input variable** since it is measured by a thermometer and used to decide whether to heat or not to heat. The desired temperature (20°C) is the **set point**. The state of the heater (e.g. the setting of the valve allowing hot water to flow through it) is called the **manipulated variable** since it is subject to control actions.

A commonly used control device called a programmable logic controller, or a PLC is used to read a set of digital and analog inputs, apply a set of logic statements, and generate a set of analog and digital outputs. Using the example in the previous paragraph, the room temperature would be an input to the PLC. The logical statements would compare the set point to the input temperature and determine whether more or less heating was necessary to keep the temperature constant. A PLC output would then either open or close the hot water valve, an incremental amount, depending on whether more or less hot water was needed. Larger more complex systems can be controlled by a Distributed Control System (DCS) or SCADA system.

## 8.11 Types of control systems

In practice, process control systems can be characterized as one or more of the following forms:

- Discrete - Found in many manufacturing, motion and packaging applications. Robotic assembly, such as that found in automotive production, can be characterized as discrete process control. Most discrete manufacturing involves the production of discrete pieces of product, such as metal stamping.
- Batch - Some applications require that specific quantities of raw materials be combined in specific ways for particular durations to produce an intermediate or end result. One example is the production of adhesives and glues, which normally require the mixing of raw materials in a heated vessel for a period of time to form a quantity of end product. Other important examples are the production of food, beverages and medicine. Batch processes are generally used to produce a relatively low to intermediate quantity of product per year (a few pounds to millions of pounds).
- Continuous - Often, a physical system is represented through variables that are smooth and uninterrupted in time. The control of the water temperature in a heating jacket, for example, is an example of continuous process control. Some important continuous processes are the production of fuels, chemicals and plastics. Continuous processes in manufacturing are used to produce very large quantities of product per year (millions to billions of pounds).

Applications having elements of discrete, batch and continuous process control are often called *hybrid* applications.

## 8.12 Six Sigma

Six Sigma is a business management strategy, originally developed by Motorola, USA in 1986, that is widely used in many sectors of industry.

Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and

business processes. It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization ("Black Belts", "Green Belts", etc.) who are experts in these methods. Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified financial targets (cost reduction and/or profit increase).

The term Six Sigma originated from terminology associated with manufacturing, specifically terms associated with statistical modeling of manufacturing processes. The maturity of a manufacturing process can be described by a sigma rating indicating its yield, or the percentage of defect-free products it creates. A six sigma process is one in which 99.99966% of the products manufactured are statistically expected to be free of defects (3.4 defects per million). Motorola set a goal of "six sigma" for all of its manufacturing operations, and this goal became a byword for the management and engineering practices used to achieve it.

Six Sigma projects follow two project methodologies inspired by Deming's Plan-Do-Check-Act Cycle. These methodologies, composed of five phases each, bear the acronyms DMAIC and DMADV.

- DMAIC is used for projects aimed at improving an existing business process. DMAIC is pronounced as "duh-may-ick".
- DMADV is used for projects aimed at creating new product or process designs.[14] DMADV is pronounced as "duh-mad-vee".

## 8.13 DMAIC

The DMAIC project methodology has five phases:

- *Define* the problem, the voice of the customer, and the project goals, specifically.
- *Measure* key aspects of the current process and collect relevant data.
- *Analyze* the data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation.
- *Improve* or optimize the current process based upon data analysis using techniques such as design of experiments, poka yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability.
- *Control* the future state process to ensure that any deviations from target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitor the process.

## 8.14 DMADV or DFSS

The DMADV project methodology, also known as DFSS ("Design For Six Sigma"),[14] features five phases:

- *Define* design goals that are consistent with customer demands and the enterprise strategy.
- *Measure* and identify CTQs (characteristics that are Critical To Quality), product capabilities, production process capability, and risks.

- *Analyze* to develop and design alternatives, create a high-level design and evaluate design capability to select the best design.
- *Design* details, optimize the design, and plan for design verification. This phase may require simulations.
- *Verify* the design, set up pilot runs, implement the production process and hand it over to the process owner(s).

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## 8.15 Quality management tools and methods used in Six Sigma

Within the individual phases of a DMAIC or DMADV project, Six Sigma utilizes many established quality-management tools that are also used outside Six Sigma. The following table shows an overview of the main methods used.

- 5 Whys
- Analysis of variance
- ANOVA Gauge R&R
- Axiomatic design
- Business Process Mapping
- Cause & effects diagram (also known as fishbone or Ishikawa diagram)
- Check sheet
- Chi-squared test of independence and fits
- Control chart
- Correlation
- Cost-benefit analysis
- CTQ tree
- Design of experiments
- Failure mode and effects analysis (FMEA)
- General linear model
- Histograms
- Pareto analysis
- Pareto chart
- Pick chart
- Process capability
- Quality Function Deployment (QFD)
- Quantitative marketing research through use of Enterprise Feedback Management (EFM) systems
- Regression analysis
- Root cause analysis
- Run charts
- Scatter diagram

*Check Your Progress*

iii. Explain Acceptance Sampling?

iv. What is six sigma?

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- SIPOC analysis (Suppliers, Inputs, Process, Outputs,Customers)
- Stratification
- Taguchi methods
- Taguchi Loss Function
- TRIZ

CASE STUDY

Total Quality Management (TQM) is a key feature of Nissan's way of working. TQM involves making customer satisfaction top priority. Given this goal, everything the organisation and its people do is focused on creating high quality. To achieve this, Nissan has to:

- understand customer requirements
- consider the processes involved in providing quality, not just the end result
- prioritise and standardise tasks to deliver quality
- educate all employees to work in this way.

In practical terms TQM involves:

- identifying customers and their requirements
- establishing and using objectives (targets) for all areas of activity
- basing decisions on researched hard facts rather than on hunches
- identifying and eliminating the root causes of problems
- educating and training employees.

TQM is an ongoing process; a way of thinking and doing that requires an 'improvement culture' in which everyone looks for ways of doing better. Building this culture involves making everyone feel their contributions are valued and helping them to develop their capabilities.

A cycle of Plan, Do, Check, Action becomes part of every employee's thinking, because it represents Nissan's way of working.

## 8.16 SUMMARY

Quality control, or QC for short, is a process by which entities review the quality of all factors involved in production. This approach places an emphasis on three aspects:

1. Elements such as controls, job management, defined and well managed processes, performance and integrity criteria, and identification of records
2. Competence, such as knowledge, skills, experience, and qualifications
3. Soft elements, such as personnel integrity, confidence, culture, motivation, team spirit, and quality relationships.

Controls include product inspection, where every product is examined visually, and often using a stereo microscope for fine detail before the product is sold into the external market. Inspectors will be provided with lists and descriptions of unacceptable product defects such as cracks or surface blemishes for example.

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The quality of the outputs is at risk if any of these three aspects is deficient in any way.

Quality control emphasizes testing of products to uncover defects and reporting to management who make the decision to allow or deny product release, whereas quality assurance attempts to improve and stabilize production (and associated processes) to avoid, or at least minimize, issues which led to the defect(s) in the first place.[citation needed]For contract work, particularly work awarded by government agencies, quality control issues are among the top reasons for not renewing a contract.

"Total quality control", also called total quality management, is an approach that extends beyond ordinary statistical quality control techniques and quality improvement methods. It implies a complete overview and re-evaluation of the specification of a product, rather than just considering a more limited set of changeable features within an existing product. If the original specification does not reflect the correct quality requirements, quality cannot be inspected or manufactured into the product. For instance, the design of a pressure vessel should include not only the material and dimensions, but also operating, environmental, safety, reliability and maintainability requirements, and documentation of findings about these requirements.

## ANSWERS TO 'CHECK YOUR PROGRESS'

(i) Total quality management or TQM is an integrative philosophy of management for continuously improving the quality of products and processes.

(ii) Statistical quality control (SQC) is the term used to describe the set of statistical tools used by quality professionals.

(iii) Acceptance sampling uses statistical sampling to determine whether to accept or reject a production lot of material.

(iv) Six Sigma is a business management strategy, originally developed by Motorola, USA in 1986, that is widely used in many sectors of industry.

(v) Process control is extensively used in industry and enables mass production of continuous processes such as oil refining, paper manufacturing, chemicals, power plants and many other industries.

## 8.17 TEST YOURSELF

1. Define TQM and explain the process its importance in manufacturing organization.
2. What are the key elements of TQM?
3. What is the basic principle of TQM?
4. What do you understand by Statistical Quality Control/
5. Define in detail the three elements of Statistical Quality Control.

6. What is six sigma? Explain its importance in today's competitive world.
7. Critically analyse the two methodologies of Six sigma.

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## 8.18 REFERENCES


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## 8.19 FURTHER READING


- *Production and Material Management*: Cundiff and Govani

# BLOCK IV

# 9 JOB SHOPS AND PRODUCTION SCHEDULING FOR JOB SHOPS

*The Chapter Covers :*



*Learning Objectives:*

After going through this chapter, you should be able to

- Explain Job Shop
- Identify problems related to job production
- Learn how to schedule production
- Learn the ways to improve productivity
- Solve bob shop complexity

## 9.1 Introduction

Every organization before setting itself to production, plans for it production schedule and the way in which production is to done for filling up consumer's or its buyers' demand on time.

## 9.2 Job Shops

Job shops are typically small manufacturing businesses that handle job production, that is, custom/bespoke or semi-custom/bespoke manufacturing processes such as small to medium-size customer orders or batch jobs. Job shops typically move on to different jobs (possibly with different customers) when each job is completed. By the nature of this type of manufacturing operation, job shops are usually specialized in skill and processes. In computer science the problem of job shop scheduling is considered strongly NP-hard.

A typical example would be a machine shop, which may make parts for local industrial machinery, farm machinery and implements, boats and ships, or even batches of specialized components for the aircraft industry. Other types of common job shops are grinding, honing, jig-boring, gear manufacturing, and fabrication shops.

The opposite would be continuous flow manufactures such as textile, steel, food manufacturing and manual labor.

## 9.3 Problems of Job production:

The basic question here is that of scheduling. When there are jobs awaiting processing on machines, each job having a pre-decided sequence of operation and processing timings, then what should be the order of loading the jobs on machines so as to optimize the expected performance standards?

**Expected performance standards could be:**

1. Mean flow time.
2. Total processing time.
3. Idle time of machines.
4. Mean earliness and lateness of jobs (Job completed before due date is its earliness. Lateness - actual completion time - due date).
5. Mean tardiness of jobs (Job completed after its due date).
6. Number of tardy jobs.
7. Mean waiting time.
8. Mean number of jobs in the system.

**The factors affecting the solution are:**

1. Total number of jobs for scheduling.
2. Total number of machines.
3. Manufacturing facilities - flow shop or job shop.
4. Nature of job arrivals - static or dynamic.
5. Evaluation criteria for scheduling.

If n (number of jobs) goes up and m (number of machines) also goes up, the problem of scheduling to that extent becomes more complex. Here there are no optimal solutions then.

The facilities in the job shop are limited, and the jobs crowd up demanding individual processing sequences. It gives rise to some peculiar problems: flow pattern problem, WIP inventories, counting of jobs, long completion time and certain unpredictable problems.

The work in this area mainly relates to static job or flow shop. However, in a large shop, the possible sequences are many. It requires further research work. More work has been in the area of dispatching rules using simulation in a dynamic environment. Scheduling has implications for both the costs and effectiveness.

## 9.4 Production Scheduling for Job shops

A typical job shop is a high-mix, low-volume (HMLV) production unit that simultaneously processes several diverse, low-quantity jobs using shared resources. The jobs have different routings, due dates, priorities, quantities, and material and resource requirements. Nowadays, the increasing product customization is creating more job shop environment in manufacturing world. For example, Mazak now makes its complete line of CNC cutting tools to order and Dell quickly assembles computers to order. Make-to-order (MTO) and engineer-to-order (ETO) production systems, and repair (MRO) systems belong to the class of job shops by the complexity of their production. In general, a job shop is a production unit where order quantities are usually small; process requirements vary with customer order; processing starts for an order only after receiving the order from customer; and many work orders are simultaneously processed using shared resources. Even the resource and material requirements often vary with the order in job shops. By this description, most of the custom manufacturing units qualify as job shops. There are some production systems where each order is a project that involves numerous tasks with dependency relations and requires many finite capacity resources for performing the tasks. From production scheduling perspective, those systems are no less complex than HMLV shops and therefore, we include such systems also in our discussion. Although most of the job shops are relatively smaller in size and revenue, from production management viewpoint, they are more complex than a large repetitive production system. Many job shops with small capital also have a difficulty to maintain raw material inventories in order to achieve short order-to-delivery lead times. Some prominent features of job shops are:

- It is difficult to predict (i) the time at which a customer will place an order, (ii) order due date (if fixed by customer), (iii) order quantity and (iv) process and material requirements of the order.
- For a majority of customer orders, production starts only after receiving an order, that is, maintaining final goods inventory to meet future demand is uncommon. This usually happens in make-to-order, engineer-to-order, and assemble-to-order production systems.
- Material acquisition process for a customer order may start only after receiving the order.

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- Using shared resources of finite capacity, a job shop simultaneously processes numerous jobs with different routings, quantities, due dates, priorities, and material and resource requirements.
- Several jobs may wait in a queue for a resource at a work center.
- Product mix and bottlenecks keep changing frequently over time.

## 9.5 Job Shop Complexity:

In any job shop, a job passes through a sequence of work centers as specified in its routing and it may wait for the required resources at those work centers. The total waiting time of the job in the entire process usually constitutes a major part of production lead time. This undesirable time is usually large, particularly for job shops with high-mix, low-volume production. It is not easy to measure the total job waiting time in such shops because (1) jobs with diverse routings are processed simultaneously, (2) the process time of an operation of a job may vary with both job and work center, (3) product mix keeps changing frequently and (4) resources have limited capacity. This complexity makes it difficult to accurately predict job progress on shop floor, WIP level at each work center, bottleneck formations, resource utilization, shop throughput and job completion times. The bottlenecks may keep moving across work centers due to the changing product mix. In job shops, it is not easy to do proactive capacity planning for preventing bottleneck formations and for improving the workflow, production lead times, on-time delivery and shop performance. Three main reasons for job shop complexity are (a) the unpredictability of the nature and receiving time of customer orders, (b) the loading of a job only after receiving a customer order and the required material, (c) and the simultaneous production of diverse, low-quantity jobs using shared resources of finite capacity.

Job shop production management involves (a) determining due dates and production start times for a stream of incoming customer orders with different routings on the basis of the existing workload and resource & material availability, (b) material planning for each order and (c) production scheduling. All the three functions are interdependent and they cannot be performed independent of one other. The difficulty in production management is aggravated by several factors including:

- Changes in customer orders
- Changes in job due dates and priorities
- Delays in material supply
- Rework / rejection due to poor quality
- Machine breakdowns
- Acceptance of hot jobs for big margins.

Each of the above factors can cause an impact on workflow, bottlenecks, WIP, lead times, on-time delivery, utilization of critical resources and shop throughput. Many job shops fix due dates for customer orders, whenever allowed by the customers, based on some average lead times (for example, three weeks), irrespective of the existing situation. Similarly, they fix production start times based on due dates and average lead times. Small and mid-sized job shops that work with low capital and receive diverse, low-volume orders with poor predictability may not be able to maintain inventory of raw materials and finished goods for many parts. Quite often, material requisition is made only after accepting such an order and production starts only after receiving the material. Some HMLV job shops produce a few make-to-stock items and maintain their inventory to promptly meet some repetitive demand. Since

material inventories have a significant impact on production cost in job shops, material for any job must be received just before the scheduled start time of the job. In fact, material requirements planning and the production schedule must be synchronized with each other. Resource-constrained production scheduling is necessary for controlling complex job shop production and predicting workflow, bottleneck formations and job completion times. The control of complex production is not effective without workflow prediction and what-if analysis of production.

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Many job shops somehow manage their production by making quick, real-time decisions on the basis of experience, intuition, common sense and simple calculations and by pushing each job from one work center to another based on the job progress. If a job is getting delayed, then they may adopt firefighting to avoid late delivery. In the simultaneous production of diverse jobs using shared resources of finite capacity, the real-time decisions for scheduling heterogeneous workload on shop floor will have a domino effect on production and that effect cannot be easily predicted. The same is true for project-based production systems that involve numerous project tasks with dependency relations. It is not easy to fully comprehend the complexity of job shop scheduling as long as the production is somehow managed by real-time scheduling and firefighting without predicting the domino effect. Long, serious discussions take place in daily production meetings in response to the changing situation in the shop and managers regularly make bold, real-time decisions to resolve fresh problems without predicting the domino effect of such decisions. There is a scope for improving job shop production performance without any capacity enhancement when the heterogeneous workload is efficiently scheduled. Meaningful and systematic production scheduling takes into account demand stream, inventories, available resource capacities, material planning, existing workload and cash flow. Its role is vital in job shops with high-mix, low-volume production.

## Various Approaches to Job Shop Scheduling:

Nowadays, many approaches like lean manufacturing, finite capacity scheduling, quick response manufacturing (QRM), CONWIP, the theory of constraints (TOC), etc are being adopted for production control and management. All these approaches provide a rough or detailed production schedule either in real time or in advance. The following is a brief discussion of a few production scheduling methods including the manual efforts.

### 1. Manual Scheduling:

Quite often, a scheduler's role is confined to tracking job progress on the shop floor and reports it to management. There are several job shops where production scheduling is simplified by the following practice:

- Due dates are fixed for customer orders on the basis of some average lead times (for example, three weeks), irrespective of the pending workload and resource availability.
- Job loading time is based on material availability and a pre-determined production lead time. Some people make a few simple calculations for the workload at critical work centers and adjust job loading times accordingly.
- Each job is pushed from one work center to another following the completion of an operation and some dispatch rule is adopted at each work center for selecting jobs (for processing) from the corresponding waiting line.
- When a job faces the risk of missing its due date, it will be expedited on high priority basis, utilizing overtime if necessary.

*Check Your Progress*

i. What do you mean by Job Shop?

ii. What is Theory of Constraints?

iii. Define QRM?

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- The job is delivered after all of its operations are completed.

Job shop production is manageable with this practice but it can lead to large WIP, long lead times, poor on-time delivery and frequent firefighting. The practice amounts to push scheduling which lean manufacturing experts always discourage. While struggling to meet the due dates, they do extensive real-time scheduling, that is, firefighting without knowing the ripple effect of their real-time decisions on production plan. Most often, the firefighting breeds itself and stays in the shop for longer times. Firefighting could be a sign of chaos, poor planning and lack of comprehensive knowledge of the dynamic nature of a job shop. It can reduce the confidence of management and customer in the due date performance of the job shop. Job shops cannot easily improve their performance until the need for firefighting is minimized without sacrificing productivity. Manual scheduling is not efficient for complex job shops that simultaneously handle at any time numerous, diverse orders with different due dates. Scientific scheduling can bring a lot of improvement in throughput, on-time delivery and resource utilization of HMLV job shops.

**1. Scheduling on Whiteboards and Excel Spreadsheets:**

Many planners still use whiteboards for production scheduling purpose. This simple, manual method could be sufficient for some small production systems. But, it is very inconvenient and ineffective for scheduling numerous operations of diverse jobs on resources of finite capacity. It is also not helpful for quick rescheduling of the workload when the actual work flow significantly deviates from the whiteboard schedule. Many software vendors extended the whiteboard concept by offering an electronic version, which facilitates manual schedule construction and modifications on Gantt chart (on computer screen). Low-cost software tools that facilitate operational level production scheduling by simple drag-and-drop operations on computer screen will be far more beneficial than whiteboards for dynamic scheduling of job shops.

Excel spreadsheets are sought for production scheduling in job shops for many reasons including:

- Almost all people familiar with personal computers can easily handle data in Excel spreadsheets
- Data required for scheduling can be easily pulled into Excel spreadsheets from a majority of ERP / MRP packages
- In Excel spreadsheets, it is easy to perform many operations on data like editing, reformatting and transformation
- Programming in VBA is useful for advanced operations on Excel data
- Some people have the perception that scheduling applications in Excel are cheaper and good enough for small job shops.

They are indeed good enough for small and simple job shop production systems. In spite of many such advantages, Excel applications have some major limitations for scheduling the production of complex job shops. Excel (plus VBA) cannot easily support a versatile scheduling paradigm and powerful logic to sufficiently address the scheduling complexity of many HMLV job shops, irrespective of the shop size. For example, Excel applications are not efficient to deal with (a) individual weekly calendars and calendar exceptions of resources, (b) changes in job priorities, (c) multiple resource requirements of operations, (d) fast and extensive what-if analysis, etc. They also lack powerful and use friendly graphic features and drag-and-drop functionality and offer little help in controlling manual errors in data entry. Although users can easily edit Excel files, the editing task is prone to human errors. As production size

and complexity increase, Excel scheduling applications tend to become massive, cumbersome and inflexible. These applications are very slow to schedule hundreds of jobs in HMLV job shops.

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However, most of these drawbacks can be avoided when best-of-breed scheduling software can directly accept data from Excel spreadsheets. For example, the users of Optisol's scheduling software, Schedlyzer can benefit from the merits of Excel as well as the scheduling power of Schedlyzer because the software can accept input data from Excel spreadsheets in a meaningful format. A small add-in software component may be needed if Excel data is not available in the required format. For small job shops, there is no guarantee that pure Excel applications with sufficient scheduling capability have less cost of ownership (including implementation and training) than some best-of-breed scheduling tools like Schedlyzer.

3. Scheduling by Project Management Software Tools:

Production management of job shops resembles resource-constrained multi-project management in many respects. However, the major differences include:

1. In many job shops, the dependency relations among tasks of a job can be expressed by a task sequence whereas the description of task dependency relations in a project usually needs a directed network.
2. In a majority of job shops, a task can be started only after finishing all of its preceding tasks. The requirement of finishing every preceding task before the start of a task may not be necessary in project environment. However, the task cannot start unless all its preceding tasks have already started.
3. Tasks in job shops are less likely to be effort driven, that is, it may not be possible to reduce the duration of a job shop task by allocating more resources.
4. Tasks in projects have longer durations with more variation.
5. Projects are more likely to be affected by major uncertain events.

Many job shop schedulers use project management (PM) tools for production scheduling. For example, ETO manufacturers and shipyards use popular PM tools for scheduling heterogeneous workload. If jobs form queues while competing for resources of finite capacity, the critical path method (a project scheduling method adopted by PM software) can generate meaningless production schedules and the schedulers helplessly accept them. A vast majority of PM packages are not satisfactory for resource-constrained scheduling of thousands of tasks because they are not efficient for automatically resolving resource conflicts. It is usually laborious to schedule and reschedule numerous jobs (with hundreds or thousands of operations) in a feasible manner when all resource conflicts in the schedule are to be manually resolved by drag-and-drop operations as required by the project management packages. These tools offer neither powerful, dependable and fast what-if analysis nor a capacity planning mechanism for production systems. However, the popular project management tools are excellent information systems with elegant graphic user interface that provides a very effective display of project / production schedules. Most of the project management tools are not powerful enough for resource-constrained, complex production scheduling involving thousands of tasks. Most of the users of such tools in production environment are unaware of the availability of powerful tools for resource-constrained scheduling.

## 4. Scheduling Modules of ERP Systems

Today, manufacturing is witnessing a rapid progress in the implementation of sophisticated enterprise-wide, integrated information systems, which are known as enterprise resource planning (ERP) systems. Companies are able to handle all their information very easily and improve the efficiency of business operations with the help of these systems. The utility of ERP systems has further increased in manufacturing execution due to the integration of shop floor data collection systems with a central database. From a customer relations point of view, these systems enable the industries to promptly give their customers real-time job status. However, many ERP systems do not fully justify the term "resource planning" because they lack strong planning and intelligent decision support modules.

There are several ERP and shop management software packages that promise to eliminate all drawbacks of the above-described scheduling methods. The ERP scheduling modules are mostly better than whiteboards and Excel spreadsheets but still inappropriate or inefficient for complex job shops. Many ERP scheduling modules are currently used by job shops mainly because (1) they replaced the laborious manual scheduling and rescheduling that is done on whiteboards and in Excel spreadsheets, (2) there is no need to provide job information separately for planning and scheduling purpose and (3) the level of scheduling knowledge on the shop floor is poor.

The modules based on MRP scheduling logic are inappropriate for job shop scheduling. Many of them may often fail to give a feasible schedule automatically that satisfies all relevant constraints. Some of them predetermine (estimate) job queuing times at different work centers and use those times in schedule development. It is almost impossible to implement such modules on the shop floor. They perform infinite capacity scheduling and determine the necessary capacity requirements, which may not always be practicable. An electronic whiteboard may be available in those modules to repair an infeasible schedule by drag-and-drop operations. Some ERP scheduling modules generate an infeasible schedule with resource conflicts and export it to a project management tool requiring a scheduler to manually repair the schedule for hours by drag-and-drop operations on Gantt chart. This approach is very laborious to reschedule a large number of jobs and perform what-if analyses in response to significant changes in production. The modules that take a lot of execution time to generate a single feasible schedule are not efficient for quick and extensive what-if analysis. Interestingly, some job shops download the production data from ERP systems and schedule the production in an Excel spreadsheet or an MS Access application.

## 5. Scheduling by Theory of Constraints (TOC):

One of the simple methods suggested for production scheduling in complex job shop is Drum-Buffer-Rope (DBR) method of the theory of constraints (TOC). It was developed by Eli Goldratt in early 1980s when companies did not have sophisticated information systems, shop floor data collection mechanism, powerful and low-cost computers, and affordable scheduling tools. After working on the development of software tools for production scheduling, Goldratt experienced the difficulty of scheduling complex production systems in those unfavorable conditions and realized a need to simplify those complex systems such that the scheduling difficulty can be eliminated.

DBR scheduling method is based on a fundamental assumption that a production system has a single resource constraint and the other resources have sufficient capacity to fully support any feasible schedule on the constraint resource. If this assump-

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tion does not hold, then factory management is required to select a resource as the constraint and increase the capacity of other resources for ensuring the applicability of the simple DBR scheduling method. The constraint resource may change over time. DBR is quite simple to understand and practice and a scheduler can easily implement it using an Excel spreadsheet. From the execution point of view, DBR involves a procedure called buffer management that addresses the system variation.

The underlying assumption of DBR concerning a single constraint resource enables us to schedule jobs on the constraint resource (in the increasing order of due dates) ignoring the capacity of all non-constraint resources. Job loading times are determined in accordance with the schedule developed on the constraint resource, taking into account the effect of uncertainty in a crude manner. The basic idea is to keep the constraint resource busy always while controlling WIP in the system by releasing jobs at right times. DBR cannot be practically effective unless its underlying assumption holds. When the assumption does not hold, the job queues caused by finite capacity resources will adversely impact the buffer management in DBR. Changing a complex job shop to support the implementation of the simple DBR scheduling method may be quite expensive sometimes and it needs strategic thinking because such changes may result in excessive resource capacities. It is rational to keep production scheduling simple in complex systems but it is important to consider what expense we must incur to make it possible.

6. Scheduling by Lean Manufacturing Practices:

Toyota production system (TPS) evolved into an inspirational world class production system over decades due to continuous, dedicated efforts of Toyota personnel. Toyota adopted and developed many concepts, principles, practices, methods and a work culture that are very effective in manufacturing. However, some of the concepts and methods like heijunka, one piece flow, takt time and kanban-based production control are not much meaningful in job shops with simultaneous production of diverse, low-quantity jobs.

The kanban system developed by Toyota is quite powerful for controlling repetitive production. It can be viewed as a real-time production scheduling system. In repetitive production, it prevents starvation of bottleneck work centers and formation of large inventory at any work center by regulating the material flow through the production system. The kanban system absorbs uncertainty, natural variation and the differences in production rates at work centers but it is mostly effective when the demand is uniform and predictable. However, in job shops with unpredictable demand and diverse jobs that move through different sequences of work centers, no kanban system can provide the predictability of workflow, WIP, lead times, resource utilization patterns and job completion times. Such predictability is essential for capacity planning and production control in complex job shops with heterogeneous workload. Kanban system cannot offer what-if analysis of dynamic production as required by job shops. Also, with kanban system it is not easy to determine a right time for loading a job into the shop based the due date, quantity and routing of the job, the resource availability and current workload on the shop floor. Kanban control does not provide a comprehensive understanding of the dynamic nature of job shops. Similarly, heijunka scheduling of TPS is not relevant to job shops that simultaneously produce many low-quantity jobs with different due dates, priorities, routings, process times, and resource and material requirements.

Since Toyota demonstrated the power of heijunka scheduling and kanban control in the management of its repetitive production, there are many attempts to forcibly implement them for production scheduling and control in complex job shops with false confidence. In job shops with simultaneous production of diverse jobs, a kanban system will be quite cumbersome with little impact on throughput and on-time delivery performance. Quick response manufacturing (QRM) is another shop floor

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control approach that can also be viewed as real-time job shop scheduling. The POLCA method of QRM is more appropriate than kanban control to address the complexity associated with multiple job routings. However, POLCA also cannot provide the required what-if analysis and predictability as required by job shops.

**7. Scheduling Algorithms:**

Researchers contributed a lot of literature on job shop scheduling which is available in books and research journals. They developed good concepts and considered interesting objectives and constraints of job shop scheduling. The objectives deal with issues like WIP, production lead time, job lateness, etc. However, the scheduling models and algorithms developed by them are largely inappropriate to the actual scheduling problems of job shops. This is mostly because (1) the available mathematical techniques are insufficient to deal with practical scheduling problems, (2) many assumptions are made for reducing a problem to a level where it can be solved by a non-trivial method, and (3) development of simple methods (heuristics) for fairly good solutions to complex practical scheduling problems is not an exciting activity for researchers, (4) researchers have a natural tendency to take a complex, rigorous view of the problems. The powerful concepts developed by researchers are buried in mathematical treatment. These researchers can develop powerful and effective solutions to practical problems when they curb their urge to publish papers.

**8. Finite Capacity Scheduling (FCS):**

Finite capacity scheduling (FCS) tools are also available for job shop scheduling. Until recently, the main disadvantages of FCS are (1) the users need to fix numerous parameters of the tool, (2) the users find the tools quite cumbersome, unfriendly and less intuitive (3) the users need a lot of training on the tools, (4) the input data is either unavailable or erroneous and (5) the tools need a lot of computing power and time. However, these tools enormously improved and overcame the disadvantages over time due to rapid advancements in hardware and software. The Windows-based tools offer a lot of flexibility, convenience and context help to users. The high-speed personal computers greatly facilitate the use of FCS tools. When top management starts looking at the schedule output from these tools, the data quality and availability will gradually improve.

With the availability of powerful information systems and sophisticated shop floor data collection systems, job shops are able to track job status and make seemingly rational decisions in real time for meeting job due dates. FCS tools depend on the same systems to provide efficient production schedules and display the dynamic workflow and bottleneck formations over time. The implementation of FCS tools brings to job shops many benefits including fast workload rescheduling, prediction of future bottlenecks and job completion times, and efficient capacity planning. FCS also has some drawbacks. Every FCS tool works with a specific scheduling model. If a scheduling problem does not fit into the underlying paradigm, the FCS solution could be meaningless even if it appears to be very sophisticated. It may be impractical to implement on the shop floor the FCS solutions that are derived purely on the basis of hours available for each resource in each time interval (day, week, month, etc). Such schedules may not specify the sequence of jobs to be loaded at each work center. Two major points of criticism about FCS are lack of ability to deal with variation and detailed schedule output. FCS logic can be suitably modified to create time buffers (as in TOC methods) for jobs at some stages to absorb the effect of variation on the schedule. The schedule output can be considered at the required level of detail. The schedulers must use some commonsense and domain knowledge while implementing these powerful tools. They can use the tools interactively to get the best schedules.

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## 9.6 Productivity Improvement in Job Shops:

Job shop productivity can be improved by the following three steps:

1. Identify improvement opportunities that are very likely to result in the increase of shop productivity,
2. Improve the situation on the shop floor adopting lean manufacturing practices like 5S, SMED, kaizen, etc along with six sigma programs.
3. Organize production operations of diverse jobs over time in an optimal manner.

The three steps can be simultaneously pursued by a job shop without any conflict. Scientific production scheduling based on an appropriate production model supports the third step while contributing to the first step to some extent. Production scheduling is as an important part of production management in complex job shops. But, many people do not seem to pay a serious attention to this important decision-making function. In simple words, this kind of production scheduling refers to determining job loading times and a chronological order of jobs to be done by each resource in a synchronous and rational manner subject to relevant constraints. It plays a central role in connecting demand, resource availability, material planning, finance and inventories. Its role is vital in job shops with high-mix, low-volume production.

### CASE STUDY - ESCOM-COPING WITH RUNWAY CAPACITY NEEDS

ESCOM is a producer of electronic home appliances, including VHS (Video Home System) television recorders, located in northern California. The packaged product weighs about 75 kg.

ESCOM was not the innovator of the system. Rather, its managers sat back and let RCA and others develop the market, and ESCOM is currently producing under license agreements. ESCOM has a conscious strategy of being a follower with new product innovations. It does not have the financial resources to be a leader in research and development.

ESCOM's present opportunity is indicated by the fact that industry sales of VHS recorders have increased 30 per cent per year for the past two years, and forecasts for the next year and the two following are even more enticing. ESCOM has established a 10 per cent market share position and feels that it can at least maintain this position if it has the needed capacity; it could possibly improve its market share if competitors fail to provide capacity at the time it is needed.

| | Year | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| Forecast, 1000 Units | 100 | 140 | 195 | 270 | 350 | 450 |
| Capacity (gap), or slack 1000 units | 5 | (35) | (90) | (165) | (245) | (345) |

The forecasts and capacity gaps are indicated in Table. ESCOM regards the first year forecast as being quite solid, based on its present market share and a compilation of several industry forecasts from different sources. It is less sure about the forecasts for future years, but it is basing these forecasts on patterns for both black and white and color TV sales during their product life cycles.

ESCOM's VHS model has a factory price of Rs 600. Variable costs are 70 percent of the price. Inventory carrying costs are 20 per cent of inventory value, 15 percentage points of which represents the cost of capital. ESCOM's facility planners estimate that a 40,000 unit plant can be built for Rs. 5 million and a 200,00 unit plant, for Rs. 10 million. Land and labour are available in the area, and either size plant can be built within a year.

*Check Your Progress*

iv. What does Job Shop Production Management involves?

v. Why ERP Scheduling modules are used by Job Shop?

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(a) What capacity plans do you think ESCOM should make for next year? Why?

(b) What longer-term capacity plans should ESCOM make? Why?

(c) What are the implications of these plans for marketing, distribution, and production?

## 9.7 SUMMARY

Job shops handle a variety of jobs, where each job is different. In batch production though there is a continuous demand for products, the rate of production exceeds that of demand, and hence there are batches. In batch production, jobs are predictable. Job shop is a different proposition, where jobs and demand both are unpredictable. Job shop handles the unique jobs each time a unique set of operations and processing time.

Job shop machines are general purposes machines organized department wise. The sequencing of each job is unique, depending upon the technological requirement. Job shop is a complex waiting line system - a job exits from a machine to wait on a new machine because of other jobs. Each machine has a waiting line of jobs. The converse is also true. Machines may wait for the job but no job is forthcoming (Idle time). Planning here is a process of prioritizing the jobs at each machine to seek the desired objectives.

## ANSWERS TO 'CHECK YOUR PROGRESS'

9.10

(i) Job shops are typically small manufacturing businesses that handle job production, that is, custom/bespoke or semi-custom/bespoke manufacturing processes such as small to medium-size customer orders or batch jobs.

(ii) One of the simple methods suggested for production scheduling in complex job shop is Drum-Buffer-Rope (DBR) method of the theory of constraints (TOC).

(iii) Quick response manufacturing (QRM) is another shop floor control approach that can also be viewed as real-time job shop scheduling.

(iv) Job shop production management involves (a) determining due dates and production start times for a stream of incoming customer orders with different routings on the basis of the existing workload and resource & material availability, (b) material planning for each order and (c) production scheduling.

(v) ERP scheduling modules are currently used by job shops mainly because (1) they replaced the laborious manual scheduling and rescheduling that is done on whiteboards and in Excel spreadsheets, (2) there is no need to provide job information separately for planning and scheduling purpose and (3) the level of scheduling knowledge on the shop floor is poor.

## 9.8 TEST YOURSELF

1. What are job shops and what is their importance?
2. Critically analyze the production scheduling process of job shops.
3. What are the various associated with job shops?
4. How can productivity be improved through the job shop mechanism?

## 9.9 REFERENCES


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## 9.10 FURTHER READING


- *Production and Material Management: Cundiff and Govani*

# 10 LAYOUT PLANNING

NOTES

***The Chapter Covers :***



***Learning Objectives:***

After going through this chapter, you should be able to

- Explain Layout Planning
- Different Objectives, Types and Factors Affecting Plant Layout
- Learn Product Oriented Layout
- Understand Work Technology
- Clarify various Work Cells

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## 10.1 INTRODUCTION

The location of the plant can have a crucial effect on the overall profitability of a project, and the scope for future expansion. Many factors must be considered when selecting a suitable plant site. The principal factors are:

- Location, with respect to the marketing area
- Raw material supply
- Transport facilities
- Availability of labor
- Availability of suitable land
- Environmental impact and effluent disposal
- Local community consideration
- Climate
- Political and strategic consideration

The term plant layout involves the development of physical relationships among building equipment and production operations which will enable the manufacturing process to be carried out efficiently. The term 'layout planning' can be applied at various levels of planning:

1. **Plant location planning** (where you are concerned with location of a factory or a warehouse or other facility.) This is of some importance in design of multi-nationally cooperating, Global-supply Chain systems.
2. **Department location Planning:** This deal with the locarion of different departments or sections within a plant/factory. This is the problem we shall study in a little more detail, below.
3. **Machine location problems:** which deal with the location of separate machine tools, desks, offices, and other facilities within each cell or department?
4. **Detailed planning:** The final stage of a facility planning is the generation, using CAD tools or detailed engineering drawings, of scaled models of the entire floor plans, including details such as the location of power supplies, cabling for computer networks and phone lines, etc.

## 10.2 Systematic Layout Planning

**The systematic layout planning** (SLP) is a tool used to arrange a workplace in a plant by locating two areas with high frequency and logical relationships close to each other. The process permits the quickest material flow in processing the product at the lowest cost and least amount of handling.

The figure below shows the steps of this methodology.

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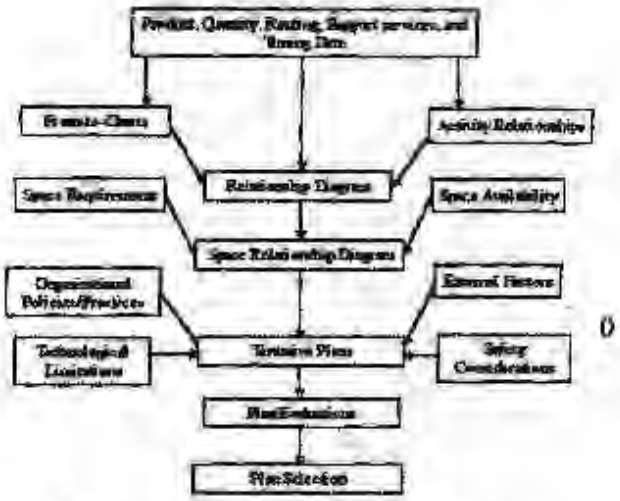


The method can be described in terms of the basic steps:

1. **Data Collection:**

   A study of the Product Mix, Quantity of each product to be produced, Routing for each product, Support services needed, and the Schedule (or the timing and transport issues related to production schedules of the products types).

2. **Flow Analysis :**

   Whence we identify what each department will be, what its inputs and outputs are likely to be, specification of physical workstations required to do the tasks (in the process plan) etc.

   At the early stages, this involves considerations of quantity of material flow, as well as overall flow lines that could be better in the implementation of departments.

   Examples include straight-line flow, S-shaped flow, U-shaped flow, or W-shaped flows. Further, even for a spine shaped system, the spine geometry can be straight line, or U-shaped (the latter case is useful if a single material receiving/delivery point is preferred.)

3. **Quantitative analysis :**

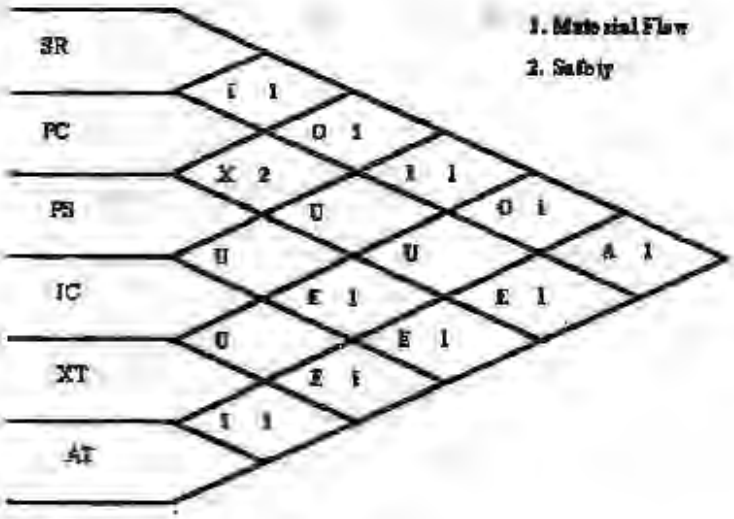
   Some factors, such as flow costs, can be quantified. Several others are not so easy to quantify. For example

   a. MH receiving and delivery stations to be kept together.

   b. Delicate testing equipment should be placed far from high vibration areas, etc.

   Such relationships can be quantified by using REL diagrams, as shown in the figure below. The relative importance of each factor is expressed in terms of subjective evaluations, ranging from A (absolutely necessary) to U (unnecessary), and X (necessary to keep apart).

   The diagram can also give reasons for such decisions. An example is shown below.




4. **Relationship Diagram :**

The quantitative and qualitative analysis is combined into a relationship diagram. One way to do this is to assign some numerical values to the A-X ratings, (typically, large integer for A-rating, 0 for U-rating, and large -ve integer for X-rating).

These ratings can then be used to determine the closeness rating for each department as the sum of all the rating-values of all links coming into it. Usually, a department with a large rating value should have significant links will many other departments, and should therefore be at the center of the layout (to be close to all other departments.)

We can now use these ratings (or their numerical values) to define the total closeness rating of different departments. If V(X) is a function which defines the value of achieving closeness between two departments, the total closeness rating of a department can be defined as the sum of its closeness rating values for all its sister departments.

To give a numerical example, assume that we allow: V(A) = 81, V(E) = 27, V(I) =9, V(O) = 3 and V(U) = 1. Then the closeness ratings corresponding to each department in the example figure above are:

| Department | Total Closeness Rating |
|---|---|
| SR | 9+3+9+3+81 = 105 |
| PC | 9+0+1+1+27 = 38 |
| PS | 58 |
| IC | 39 |
| XT | 35 |
| AT | 165 |

In the above, the X-ratings were ignored in order to allow each department to have a fair chance in placement in the initial design of the layout. The real value of this rating will be used later, when we put some effort into modification on the first-guess solution.

Forming the first guess solution (greedy algorithm):

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Step 1. Notice that AT has the highest rating, and so is placed in the center of the layout (why ?)

Step 2. The next highest ranked department is SR, which may be placed adjacent to AT due to their mutual A-rating. We put it on top of AT.

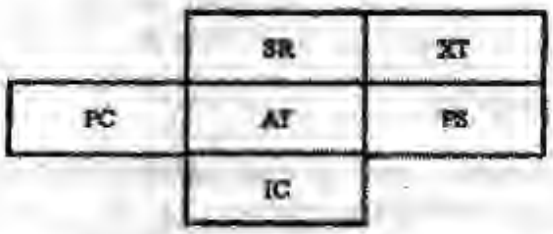
Step 3. Next up is PS, which should go adjacent to AT (since V(AT,PS) is the highest rated closeness value for PS.

Step 4. Next comes XT, which should be close to PS.

Step 5. Next is IC, which should be close to AT and is placed below it.

Step 6. Finally, we have PC, which must stay away from PS.

Using these directions, we have a first attempt at the layout as follows:




Notice the odd shape of the final layout. This does not matter, since we still have not considered the relative sizes of the departments. But before considering that, we must also attempt to improve upon our greedy solution.

One heuristic to do so is called the 2-Opt method. A k-opt method is said to have converged when any switching between k variables (in this case, locations of departments) cannot improve upon the objective (in our case, minimization of the total MH cost).

The 2-Opt procedure to improve on the greedy solution is pretty straightforward, and described rather well in your text (Askin and Standridge, pp 219). In summary, it is a hill-climbing heuristic, in which, starting from the initial solution, at each step we compute the reduction (if any) in cost associated with switching the positions of each pair of departments.

The pair which yields the maximum reduction in costs (steepest local benefit) is selected at this step. The switch is made, and the procedure continues, until at some stage, we are unable to find any pair-switch which improves on the MH cost.

In the above, the MH cost associated with any pair of departments is often based on the estimated MH cost factor, wij that we computed earlier, multiplied by an estimate of the distance between the two cells.

5. Space requirements :

These are determined based on industrial standards, equipment required, shelf space required, etc.

6. **Space availability :**

   This is determined based on the economic analysis, as well as on other constraints that may arise (especially if the system is to be housed in an existing facility). The last two considerations will give an estimate of total space for each department, and sometimes also the shape of each department (based on flow type within the department).

7. **Space relationship diagram :**

   In this part, we substitute in the actual area on each department, and fit the departments into the available space. Usually, the solution methods may be computer-assisted heuristics, or just direct visual methods.

8. **Putting in the constraints :**

   Finally, other existing constraints are employed to cut down the number of feasible solutions, to result in a small set of solutions. from among these, direct comparison can be used to rank, eliminate, or select the optimum design.

## 10.3 Plant layout planning

- Plant layout planning includes decisions regarding the physical allocation of the economic activity centers in a facility.
  - An economic activity center is any entity occupying space.
  - The objective of plant layout planning is a more effective work flow at the facility, allowing workers and equipment being more productive.
- Facility layout techniques apply to the case where several physical means have to be located in a certain area, either industrial processes or services.
- The objective of the chapter is not only Plant layout but re-layout also (most common situation for a company).
- To carry out an appropriate plant layout, it's important to take into account the business strategic and tactical objectives

Example: space requirements/cost per m2 in Malls; accessibility/privacy in offices.

**To make a decision about layout planning, 4 different questions must have an answer:**

- Which centers do we have to consider?
- How much space and capacity is required for each center?
  - If there is not enough space, productivity may be reduced.
  - Too much space is expensive and may also reduce productivity.
- How must the space be configured at each center?
  - Space quantity, shape and the elements of the work center are related to each other.

NOTES

- Where should each center be located at within the facility?
  - The allocation of the different centers may affect productivity.

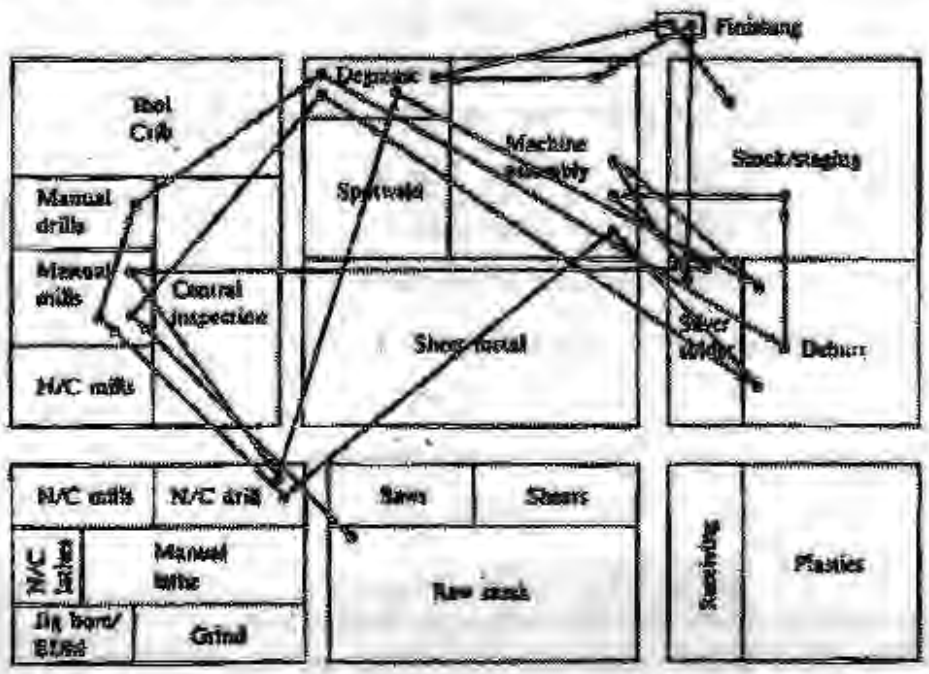
- The plant layout process starts at an aggregate level, taking into account the different departments. As soon as we get into the details, the different issues arise, and the original configuration may be changed through a feedback process.
- Most (if not all of them) layouts are designed properly for the initial conditions of the business, although as long as the company grows and has to be adapted to internal and external changes, a re-layout is necessary.
- The reasons for a re-layout are based on 3 types of changes:
  - Changes in production volumes.
  - Changes in processes and technology.
  - Changes in the product.

The frequency of the re-layout will depend on the requirements of the process

**Symptoms that allow us to detect the need for a re-layout:**

- Congestion and bad utilization of space.
- Excessive stock in process at the facility.
- Long distances in the work flow process.
- Simultaneous bottle necks and workstations with idle time.
- Qualified workers carrying out too many simple operations.
- Labor anxiety and discomfort. Accidents at the facility.
- Difficulty in controlling operations and personnel.

The figures below give us an example of a typical plant re layout -



## 10.4 Objectives of Plant Layout

- The main objective consists of organizing equipment and working areas in the most efficient way, and at the same time satisfactory and safe for the personnel doing the work. The other are -

- Sense of Unity
  - The feeling of being a unit pursuing the same objective.
- Minimum Movement of people, material and resources.
- Safety
  - In the movement of materials and personnel work flow.
- Flexibility
  - In designing the plant layout taking into account the changes over short and medium terms in the production process and manufacturing volumes.

These main objectives are reached through the attainment of the following facts:

- Congestion reduction.
- Elimination of unnecessary occupied areas.
- Reduction of administrative and indirect work.
- Improvement on control and supervision.
- Better adjustment to changing conditions.
- Better utilization of the workforce, equipment and services.
- Reduction of material handling activities and stock in process.
- Reduction on parts and quality risks.
- Reduction on health risks and increase on workers safety.

- Moral and workers satisfaction increase.
- Reduction on delays and manufacturing time, as well as increase in production capacity.

All these factors will not be reached simultaneously, so the best solution will be a balance among them.

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## 10.5 Factors affecting Plant Layout

The final solution for a Plant Layout has to take into account a balance among the characteristics and considerations of all factors affecting plant layout, in order to get the maximum advantages.

The factors affecting plant layout can be grouped into 8 categories:

- Materials
- Machinery
- Labor
- Material Handling
- Waiting Time
- Auxiliary Services
- The building
- Future Changes

## 10.6 Types of Plant Layout

The production process normally determines the type of plant layout to be applied to the facility:

- Product oriented plant layout
  - Machinery and Materials are placed following the product path.
- Process oriented plant layout (Functional Layout).
  - Machinery is placed according to what they do and materials go to them.
- Combined Layout
- Fixed Layout

*Check Your Progress*

i. What is SLP?

ii. What is Data Collection?

iii. What is Product Oriented Layout?

## 10.7 Product Oriented Layout

In a product layout, the workstations and equipment are located along the line of flow of the work units. Usually, work units are moved along a flow line which is powered by a conveyor. Work is done in small amounts at each of the workstations on the work unit. This means that to use the product layout the total work must be dividable into small tasks that can be assigned to the workstations. Because the workstations do small amounts of work, the stations are specialized in their tasks with specialized equipment and tooling, which leads to high proficiency and reduced cycle time. And this also leads to a higher production rate.

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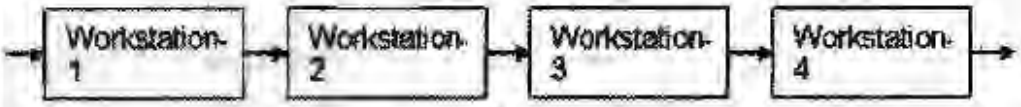
In this type of layout the machines and equipments are arranged in one line depending upon the sequence of operations required for the product. It is also called as line layout. The material moves to another machine sequentially without any backtracking or deviation i.e the output of one machine becomes input of the next machine. It requires a very little material handling.

It is used for mass production of standardized products.

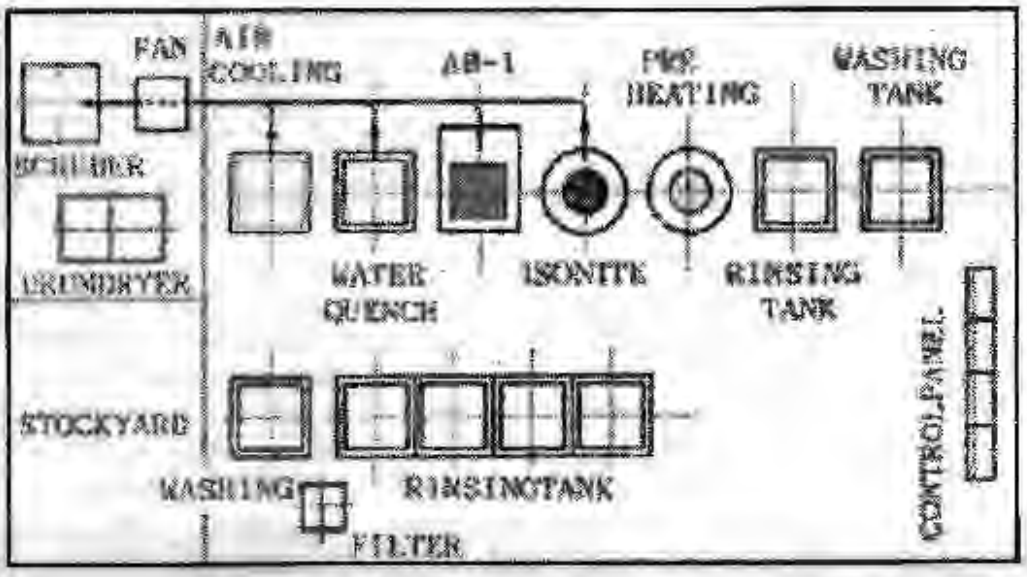
## Product oriented plant layout

- Advantages:
  - Reduced material handling activities.
  - Work in Process almost eliminated.
  - Minimum manufacturing time.
  - Simplification of the production planning and control systems.
  - Tasks simplification.
- Disadvantages:
  - No flexibility in the production process.
  - Low flexibility in the manufacturing times.
  - High capital investment.
  - Every workstation is critical to the process.- The lack of personnel or shut down of a machine stops the whole process.
  - Monotonous work.




Example of product oriented plant layout

Process layout



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The process layout is a simple layout, outstanding for short to average manufacture amount. It is exceptional for middle to lofty production dissimilarity. With its uses, the workers should be accomplished and competent. It has a high work in process. Its main benefit is the low production rate. Initial investment in process layout is low. Diverse amount of machine consumption may be attained in process layout as appliance is not devoted to a sole creation. It has great suppleness and extent of growth survive in this layout.

The process layout is otherwise called as functional layout or job shop layout. Process Layout engages assembling mutually in one section based leading their operational kind. Process Layout is handiness for inspection and supervision. In Industrial engineering, Process Layout is the ground plan of the plant, which is fits by industrial engineers to get better the competence organizing tools consistent with their purpose. In this layout, the major plan is to fix up or collect machinery or equipments of the similar role keen on one group or division. Similar machines or similar operations are situated at one rest by means of the functions.

Process layout are established mainly in occupation shops, or firm that produce modified, short sound goods which may need dissimilar giving out desires and progressions. Process layouts are service pattern in which processes of a comparable nature or function are set mutually. Services which employ process layouts comprise hospitals, banks, auto repair, libraries and universities. Recovering process layout engages the reduction of transportation charge, detachment or occasion.

### Advantages of Process layout:

- Lower initial capital investment is required.
- There is high degree of machine utilization, as a machine is not blocked for a single product
- The overhead costs are relatively low
- Breakdown of one machine does not disturb the production process.
- Supervision can be more effective and specialized.
- Greater flexibility of resources.

### Disadvantages of Process layout:

- Material handling costs are high due to backtracking
- More skilled labor is required resulting in higher cost.
- Work in progress inventory is high needing greater storage space
- More frequent inspection is needed which results in costly supervision

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COMBINED LAYOUT:

1. A combination of process & product layout is known as combined layout.
2. Manufacturing concerns where several products are produced in repeated numbers with no likelihood of continuous production, combined layout is followed

FIXED POSITION OR LOCATION LAYOUT:

Fixed position layout involves the movement of manpower and machines to the product which remains stationary. The movement of men and machines is advisable as the cost of moving them would be lesser. This type of layout is preferred where the size of the job is bulky and heavy. Example of such type of layout is locomotives, ships, boilers, generators, wagon building, aircraft manufacturing, etc.


**Advantages of Fixed position layout:**

- The investment on layout is very small.
- The layout is flexible as change in job design and operation sequence can be easily incorporated.
- Adjustments can be made to meet shortage of materials or absence of workers by changing the sequence of operations.

**Disadvantages of Fixed position layout:**

- As the production period being very long so the capital investment is very high.
- Very large space is required for storage of material and equipment near the product.
- As several operations are often carried out simultaneously so there is possibility of confusion and conflicts among different workgroups.

## 10.9 Work cells

A work cell is an arrangement of resources in a manufacturing environment to improve the quality, speed and cost of the process. Work cells are designed to

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improve these by improving process flow and eliminating waste. They are based on the principles of Lean Manufacturing as described in ***The Machine That Changed the World by Womack,*** Jones and Roos.

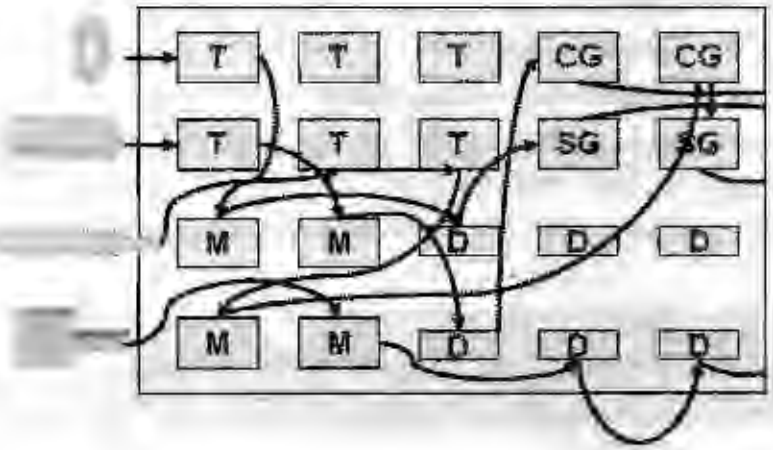
Classical manufacturing management approaches dictate that costs be lowered by breaking the process into steps, and ensuring that each of these steps minimizes cost and maximizes efficiency. This discrete approach has resulted in machines placed apart from each other to maximize the efficiency and throughput of each machine. The traditional accounting for machine capitalization is based on the number of parts produced, and this approach reinforces the idea of lowering the cost of each machine (by having them produce as many parts as possible.) Increasing the number of parts (WIP) adds waste in areas such as Inventory and Transportation.

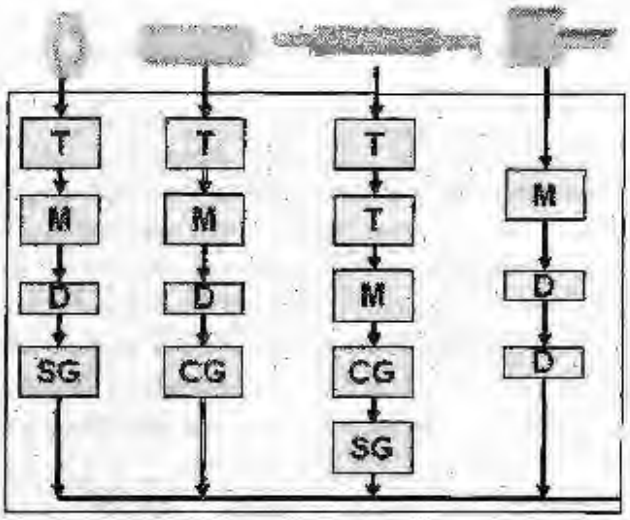
Large amounts of excess Inventory often now accumulate between the machines in the process for reasons to do with 'unbalanced' line capacities and batch processing. In addition, the parts must now be transported between the machines. An increase in the number of machines involved also will reduce each worker's multi-skilling proficiency (since that would need them to learn how to operate multiple machines, and they too will need to move between those machines.)

Lean focuses on optimizing the end-to-end process as a whole. This enables a focus in the process on creating a finished product at the lowest cost (instead of lowering the cost of each step.) A common approach to achieving this is known as the work cell. Machines involved in building a product are placed next to each other to minimize transportation of both parts and people (an L-shaped desk with upper shelves is a good office example, which enables many office equipment to be within the reach of a worker). This will minimize waste in both transportation and in the storage of excess inventory.

At first glance, lean work cells may appear to be similar to traditional work cells, but they are inherently different. For instance, lean work cells must be designed for minimal wasted motion, which refers to any unnecessary time and effort required to assemble a product. Excessive twists or turns, uncomfortable reaches or pickups, and unnecessary walking all contribute to wasted motion and may put error inducing stress upon the operator. Work cells can often be reconfigured easily to allow the adaptation of the process to fit at a given time time. This flexibility allows the work content to be adapted as demand or product mix changes.

Given below is the typical arrangement of a work cell






## 10.10 Group Technology

**Group Technology** or GT is a manufacturing philosophy in which the parts having similarities (Geometry, manufacturing process and/or function) are grouped together to achieve higher level of integration between the design and manufacturing functions of a firm. The aim is to reduce work-in-progress and improve delivery performance by reducing lead times. GT is based on a general principle that many problems are similar and by grouping similar problems, a single solution can be found to a set of problems, thus saving time and effort. The group of similar parts is known as **part family** and the group of machineries used to process an individual part family is known as **machine cell**. It is not necessary for each part of a part family to be processed by every machine of corresponding machine cell. This type of manufacturing in which a part family is produced by a machine cell is known as **cellular manufacturing**. The manufacturing efficiencies are generally increased by employing GT because the required operations may be confined to only a small cell and thus avoiding the need for transportation of in-process parts.

**CASE STUDY - General principles followed by MNC'S for Plant Layout**

Plant layout is often a compromise between a numbers of factors such as:

- The need to keep distances for transfer of materials between plant/storage units to a minimum to reduce costs and risks;
- The geographical limirations of the site;
- Interaction with existing or planned facilities on site such as existing roadways, drainage and utilities routings;
- Interaction with other plants on site;
- The need for plant operability and maintainability;
- The need to locate hazardous materials facilities as far as possible from site boundaries and people living in the local neighbourhood;
- The need to prevent confinement where release of flammable substances may occur;
- The need to provide access for emergency services;
- The need to provide emergency escape routes for on-site personnel;
- The need to provide acceptable working conditions for operators.

The most important factors of plant layout as far as safety aspects are concerned are those to:

- Prevent, limit and/or mitigate escalation of adjacent events (domino);
- Ensure safety within on-site occupied buildings;
- Control access of unauthorised personnel;
- Facilitate access for emergency services.

In determining plant layout designers should consider the factors in outlined in the following sections.

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**Inherent safety**

The major principle in Inherent Safety is to remove the hazard altogether. The best method to achieve this is to reduce the inventory of hazardous substances such that a major hazard is no longer presented. However, this is not often readily achievable and by definition no COMAH facility will have done so. Other possible methods to achieve an Inherently Safer design are:

- Intensification to reduce inventories;
- Substitution of hazardous substances by less hazardous alternatives;
- Attenuation to reduce hazardous process conditions i.e. temperature, pressure;
- Simpler systems/processes to reduce potential loss of containment or possibility of errors causing a hazardous event;
- Fail-safe design e.g. valve position on failure.

Plant layout considerations to achieve Inherent Safety are mainly those concerned with domino effects (see below).

**The Dow / Mond Indices**

These hazard indices are useful for evaluating processes or projects, ranking them against existing facilities, and assigning incident classifications. They provides a comparative measure of the overall risk of fire and explosion of a process, and are useful tools in the plant layout development stage since they enable objective spacing distances to be taken into account at all stages.

The methodology for undertaking a rapid ranking method that is based on the Dow / Mond index is detailed in ILO, PIACT, Major Hazard Control: A practical manual, 1988.

Although these are useful rule-of thumb methodologies for first consideration of plant layout, they do not replace risk assessment. The distances derived between plant units using these systems are based upon engineering judgement and some degree of experience rather than any detailed analysis.

*Check Your Progress*

iv. What are Work Cells?

v. Explain Group Technology?

**Domino effects**

Hazard assessment of site layout is critical to ensure consequences of loss of containment and chances of escalation are minimised. Domino may be by fire, explosion (pressure wave and missiles) or toxic gas cloud causing loss of control of operations in another location.

**Fire**

A fire can spread in four ways:

- Direct burning (including running liquid fires);
- Convection;

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- Radiation;
- Conduction.

The spread of fire from its origin to other parts of the premises can be prevented by vertical and horizontal compartmentation using fire-resisting walls and floors. Further information may be found in BS 5908 : 1990. Consideration should also be given to the spread of flammable material via drains, ducts and ventilation systems. Delayed ignition following a release may result in spread of flames through such systems via dispersed flammable gases and vapours.

Protection against domino effects by convection, conduction and radiation can be achieved by inherent safety principles i.e. ensuring that the distances between plant items are sufficient to prevent overheating of adjacent plants compromising safety of those plants also. Where this is not possible due to other restrictions, other methods such as fire walls, active or passive fire protection may be considered.

**Explosion**

Explosion propagation may be directly by pressure waves or indirectly by missiles. As for fires, inherently safe methods that should be considered are:

- arranging separation distances such that damage to adjacent plants will not occur even in the worst case;
- provision of barriers e.g. blast walls, location in strong buildings;
- protecting plant against damage e.g. provision of thicker walls on vessels;
- directing explosion relief vents away from vulnerable areas e.g. other plants or buildings, roadways near site boundaries.

However, the latter may not provide practical solutions, particularly against missiles, and risk analysis may be required to prove adequate safety.

Toxic gas releases

Toxic gas releases may cause domino effects by rendering adjacent plants inoperable and injuring operators. Prevention/mitigation of such effects may be affected by provision of automatic control systems using inherently safer principles and a suitable control room (see section below on Occupied Buildings).

Reduction of consequences of event on and off Site

In addition to the measures described in the sections above, Plant Layout design techniques applicable to the reduction of the risks from release of flammable or toxic materials include:

- Locating all high-volume storage of flammable / toxic material well outside process areas;
- Locating hazardous plant away from main roadways through the site;
- Fitting remote-actuated isolation valves where high inventories of hazardous materials may be released into vulnerable areas;
- Provision of ditches, dykes, embankments, sloping terrain to contain and control releases and limit the safety and environmental effects;
- Siting of plants within buildings as secondary containment;
- Siting of plants in the open air to ensure rapid dispersion of minor releases of flammable gases and vapours and thus prevent concentrations building up which may lead to flash fires and explosions;

- Hazardous area classification for flammable gases, vapours and dusts to designate areas where ignition sources should be eliminated.

Risk management techniques should be used to identify control measures that can be adopted to reduce the consequences of on or off site events. See references cited in further reading material.

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**Positioning of occupied buildings**

The distance between occupied buildings and plant buildings will be governed by the need to reduce the dangers of explosion, fire and toxicity. In particular, evacuation routes should not be blocked by poor plant layout, and personnel with more general site responsibilities should usually be housed in buildings sited in a non-hazard area near the main entrance. Consideration should be given to siting of occupied buildings outside the main fence. In all cases occupied buildings should not be sited downwind of hazardous plant areas. Further guidance is available in standard references.

## 10.11 SUMMARY

Plant layout refers to the arrangement of physical facilities such as machines, equipment, tools, furniture etc. in such a manner so as to have quickest flow of material at the lowest cost and with the least amount of handling in processing the product from the receipt of raw material to the delivery of the final product. Planning the layout of machines and assembly lines has always been given priority in our operations.

International competition and technological advancements, have led to significant change in the planning process. We use computers to create productive layout and design alternatives. Participative management and employee involvement have become an integral part of effective layout planning as well.

Selling new projects and effective implementation are the results of sound layout practices reflecting the ever changing work place environment.

## ANSWERS TO 'CHECK YOUR PROGRESS'

(i) The systematic layout planning (SLP) is a tool used to arrange a workplace in a plant by locating two areas with high frequency and logical relationships close to each other.

(ii) Data Collection: A study of the Product Mix, Quantity of each product to be produced, Routing for each product, Support services needed, and the Schedule (or the timing and transport issues related to production schedules of the products types).

(iii) In a product layout, the workstations and equipment are located along the line of flow of the work units.

(iv) A work cell is an arrangement of resources in a manufacturing environment to improve the quality, speed and cost of the process. Work cells are designed to improve these by improving process flow and eliminating waste.

(v) Group Technology or GT is a manufacturing philosophy in which the parts having similarities are grouped together to achieve higher level of integration between the design and manufacturing functions of a firm.

## 10.12 TEST YOURSELF

NOTES

1. Define layout. What is the importance of layout planning?
2. What are the various types of Plant layout available in manufacturing?
3. Explain the various advantages and disadvantages of Product oriented layout?
4. What is the importance of Facility Layout?
5. What are the various factors affecting layout selection decision?
6. Explain the concept of work cells and group technology.

## 10.13 REFERENCES


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## 10.14 FURTHER READING

- *Production and Material Management: Cundiff and Govani*