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UNIT - I

INTRODUCTION TO PRODUCTION AND OPERATION MANAGEMENT

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1.1 INTRODUCTION

This unit starts with a definition of a system. In this unit production system and its objectives are explained along with the components of a system. The history of operations management is portrayed. The various functions of production system and their interlinking are explained through a flow chart. The components of computer, integrated manufacturing and their purpose are dealt. Finally, the recent trend in the operations, namely, **Global Supply Chain** is introduced in this unit.

1.2 LEARNING OBJECTIVES

- To know the importance of the production system in an organization.
- To understand the link between various activities of the production system.
- To comprehend the history of operations management.
- To understand the components of computer integrated manufacturing

1.3 SYSTEM

It consists of elements or components. The elements or components are interlinked together to achieve the objective for which it exists. Eg: human body, educational institutions, business organizations.

Components of a system:

The input, processing, output and control of a system are called the components of a system.

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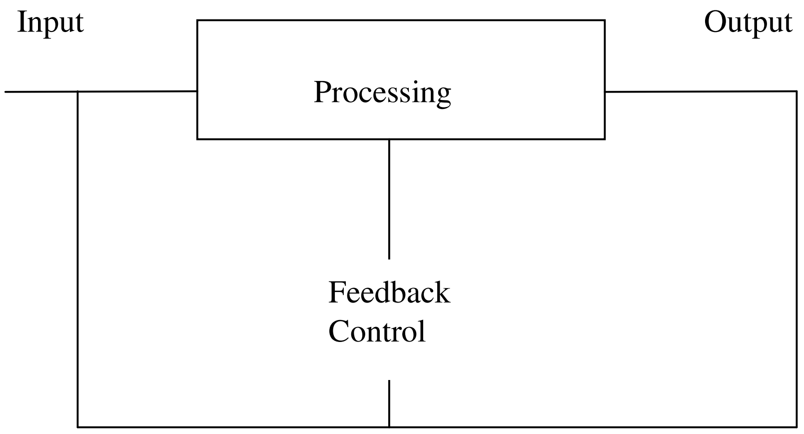
Figure 1.1 - Components of a system



Control:

There are two types of control, namely **Proactive Control and Reactive Control.**

Proactive Control:

When an operation is carried out on a product in a workstation, the quality inspector goes to the workstation and inspects the product. When the samples that he has taken for the inspection are not confirming to the quality, he stops the machine and identifies the reason for the deviation and corrects the problem, so that the produced product thereafter conform to the specifications. This type of control prevents any major quality setback after the production. This is an example for proactive control.

Reactive Control:

In a planning period, usually the quality target is fixed. Suppose, an organization feels to fix 5% defective is safe in the targeted production quantity and assumes that at the end of the planning period it finds that the defective output exceeds the targeted defective products. Then, it has to find out the reason for the deviations, namely, whether the problem is due to the method of doing the work or the resources used in the process. Then the planner uses this knowledge to prevent any problem in the future. Thus a Reactive Control is a post morterm case.

1.3.1 Business System:

The business organization is classified into different subsystems based on the functions like marketing, production/operation, finance and human resource etc.

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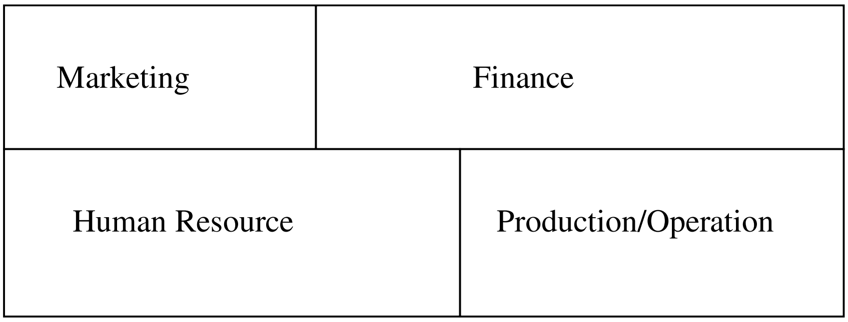
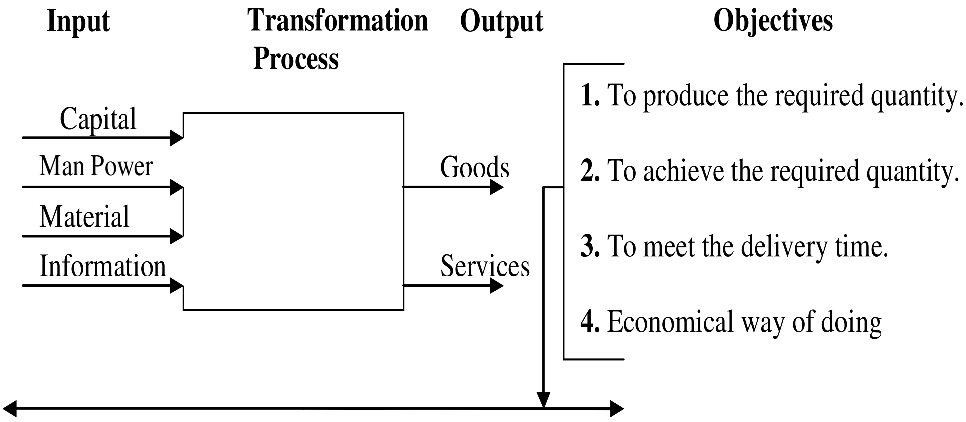
Figure 1.2 – Business System



Each subsystem will have more sub subsystems.

1.3.2 Production / Operation System

Figure 1.3 – Production / Operation System



Operations Management

Operation system is either manufacturing sector or service sector. The input requirements are shown in figure1.3 The transformation process, in which part of the value addition takes place to get the required quantity of the product or services with the targeted quality within the specified time period, is carried out in a most economical way. Operation Management Plan coordinates and controls all the activities in the operation system to achieve the stated objectives.

Thus (the activities listed in the diagram) the Operations Management activities, ensure the objective of quantity, quality, delivery time and economical way of doing work. The communication link between the various activities are shown in the figure1.3.

Each activity is dealt in detail in different sections of this material. This figure (figure1.3) will be very much appreciated after getting a clear understanding of all the activities.

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1.3.3 What is operation management (OM)?

Operation Management is a way or means through which the listed objectives of an operating system is achieved. There is always a confusion between the word OM & PM (Production Management). It is accepted norm that OM includes techniques which are enabling the achievement of operational objectives in an operation system.

The operation system includes both manufacturing sector as well as service sector, but when you use the word PM, you should be careful to note that it refers to the manufacturing sector but not the service sector. Suppose, you are designing a layout for the hospital you should say that you are applying Operations Management Technique not the Production Management Technique.

When you design a layout for a manufacturing sector you can say that you are applying Production Technique or Operation Technique or vice versa.

From, the above discussion we can come to a conclusion that production management is a subset of Operations Management.

Review questions –

1. What are the components of a system?
2. What are the differences between the Production Management and the Operations Management?
3. List the objectives to be fulfilled by an Operation System.

1.4 HISTORY OF OM

Table 1.1 – History of OM

Year / Period of Concept	Concept/Tools and System Used	Developers/ Originators
(14-16) Century	Evolution of Production system	
18th Century	New Technology for Production Process Management	Adam Smith and harles Babbage
1895	Scientific Management Principles (Work Study) Motion Study for Psychological Factors Activity Scheduling Chart Gantt	F.W.T. Taylor Frank & Lillian Gilbreth Henry
1935	Hawthrone Studies of Worker Motivation	Elton Mayo
1950’s	Operation Research for Decision Making Long term Medium term, Short term decision by	Many Researcher

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	Critical Path Method (CPM), Program Evaluation and…… Technique (PERT), Waiting-Line Theory	
1970's	Computers for Inventory Control Material Resource Planning (MRP)	IBM, Joseph Orlicky, Oliver Wieght
1980's	Just In Time (JIT), Total Quality Control (TQC) Kanban System, CAD/CAM, Computer Integrated Manufacturing (CIM) Flexible Manufacturing System (FMS)	Toyota
1990's	1.Total Quality Management (TQM), Concurrent (CIM), Engineering, Value Engineering 2. Business Process Engineering 3. Supply Chain Management	Asqc(U.S.). IOS (England), Michael Hammer Oracle, SAP (Germany)
2000's	Logistics, Enterprise Resource Planning (ERP), E-Commerce, E-Business	

Review questions -

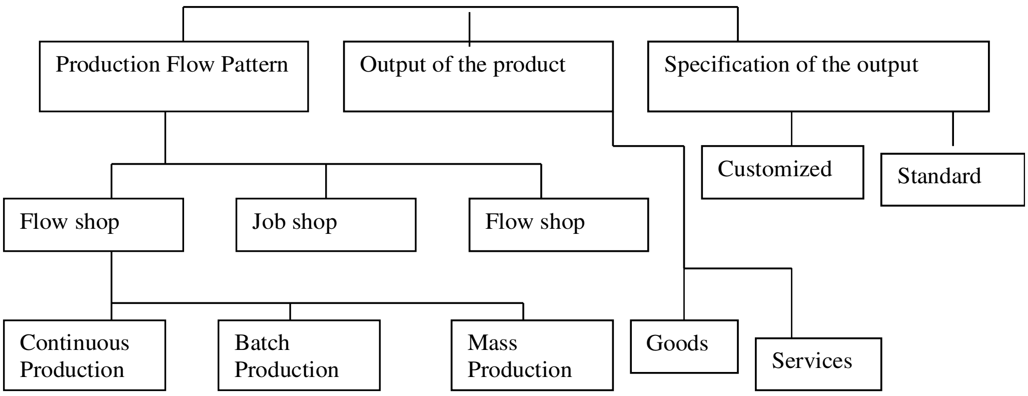
1. What is the contribution of GANTT?
2. Who is the father of Scientific Management?

1.5 TYPES OF OPERATION SYSTEM

The type of Operation System to be adopted should be known to the people, and then only you may choose the system based on the nature of the product that you are going to manufacture. The types of operation system are classified based on the following criteria.

Product flow pattern in conversion system
Output of the product
Specification of the output

Figure 1.5 - Types of Operation System



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The characteristics of the Operation System based on the product flow pattern:

1.5.1 Flow Shop

In this kind of production, the productive resources are arranged according to the sequence of operation required by the product design.

Assume that you are engaged in the ready to wear clothing, if you want to adopt the flow shop production, then the productive resources are kept according to the sequence of operations required by the product like
Cutting
Joining by sewing
Adding, buttons, zippers etc
Quality checking
Packaging
Mostly Flow shop production are adopted when there is untapped market for the product, customers are price sensitive and more competition in the market.

Flow shop production as shown in the figure is further divided into **Continuous Production**, **Mass Production** and **Batch production**.

1.5.1.1 Continuous Production

The industries involved in the following activities are classified as Continuous Production

- Oil refining.
- Fertilizer production.
- Chemical processing etc.
- In this type of production the product flows continuously without much interruption.
- This type of production lacks in flexibility.

1.5.1.2 Mass Production

The industries involved in the following activities are classified as the Mass Production Industries:

Auto Manufacturing
TV Manufacturing
Cigarettes
This kind of **flow shop** produces the same type of output, it has little flexibility compared to **Continuous Production.**

1.5.1.3 Batch Production

The industries involved in the following activities are classified as the **Intermittent Production.**

- Shoe manufacturing
- Bottling plant
- Cloth manufacturing

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Here the basic design of the product is the same but the specification of the product differs. The production gets interrupted when the system switches over to other type of the product specification. The products are similar in nature but not identical.

The Characteristics of Flow Shop Production:

Refer Table1.2

Table 1.2 - The Characteristics of Flow shop Production

Product	The products are standardized.
Conversion	Special purpose equipments, designed for the specific
Resources	process of the product.
Work force	Specialized people, doing the repetitive jobs.
Workforce Job satisfaction	Job satisfaction among the employee is low because of the repetitive nature of job, results in boredom, more turnover and absentees.
Work-in-progress inventory	Productive resources are balanced that result in less work in progress inventory.
Cycle time	Cycle time per unit is relatively low
Cost of production	Cost of production per unit is relatively low.
Quantity of production	Comparatively quantity of production is more
Varieties	Products to be produced of less variety.
Flexibility	This kind of production lacks in flexibility.
	Small change in the product design needs the change in production system abnormally.
Production planning and control	Since less varieties of product are produced for longer period, the production planning and control activities are inbuilt in the system itself, so the production planning and control activities are not a complex one.

1.5.2 Job Shop

In the case of Job Shop Production, the products are mostly customized products. Based on the customer requirements, the products are produced. The productive resources are kept according to the function.

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The industries involved in the following activities are classified as the Job Shop production:

- Auto repairing
- Hospital
- Machine shop

The Characteristics Of Job Shop Production.

Table 1.3

Product	The products are of order based mostly non standardized.
Conversion of Resources	General purpose equipment, grouped according to their functions.
Work Force	Skilled people, doing multi skilled work.
Work force satisfaction	Job satisfaction among the employee is high because the operator role is multifaceted.
Work in Progress Inventory	There is lot of waiting time for the product to be manufactured in the system that results in more in process inventory.
Cycle time	Because of more waiting time for the product in the production line that results more manufacturing cycle time comparatively.
Cost of Production	Cost of production per unit is relatively high.
Quantity of production	Since it is order based production, quantity produced per unit type is relatively less.
Varieties	The production system capable of producing more type of products.
Flexibility	This system has more flexibility any change in the design of the product could be incorporated without much problem.
Production Planning and Control	The arrival, the operations demanded and the operations time required by the order mostly uncertain. This makes the jobs of production planning and control difficult.

1.5.3 Project Production

This refers to the industries involved in the production of one type of complex products like, ship construction, dam construction, bridge construction, research and development etc.

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Project production consists of many activities where the activities are interlinked, time phased and resources committed.

In this kind of production, scheduling the activities is important so that you can complete the project within the time and budget constraint. The resources, namely, manpower, machines, material are brought to the workplace where the product is manufactured. There is no movement of the product.

Review Questions

1. Which type of the production system in the process inventory is less?
2. In which type of production system flexibility is more?
3. Tell the important characteristic of Batch Production about the product?
4. In which type of production system there is no product movement?

1.6 COMMUNICATION IN POM

As it is mentioned in the above section, operation management is meant to achieve the objectives for which the operation system is intended for. Based on the objective set by the top management, the system design is established. The system design involves designing the product and process, designing the methods, measuring the work, identifying the location, and designing the layout. By keeping the system design as a framework in the aggregate planning various production alternatives are analyzed and the best feasible production alternatives are chosen.

Then keeping the aggregate planning as a input, resource allocation and sequencing of day to day activities are done. The inventory also kept at minimum to satisfy the organization's inventory objectives. The maintenance activity ensures the availability workstations. Quality control ensures the quality in the input, processing and output stages of production system. (See figure 1.4- Communication in POM).

Review Questions-

1. List the activities in system design?
2. What are the phases of scheduling?

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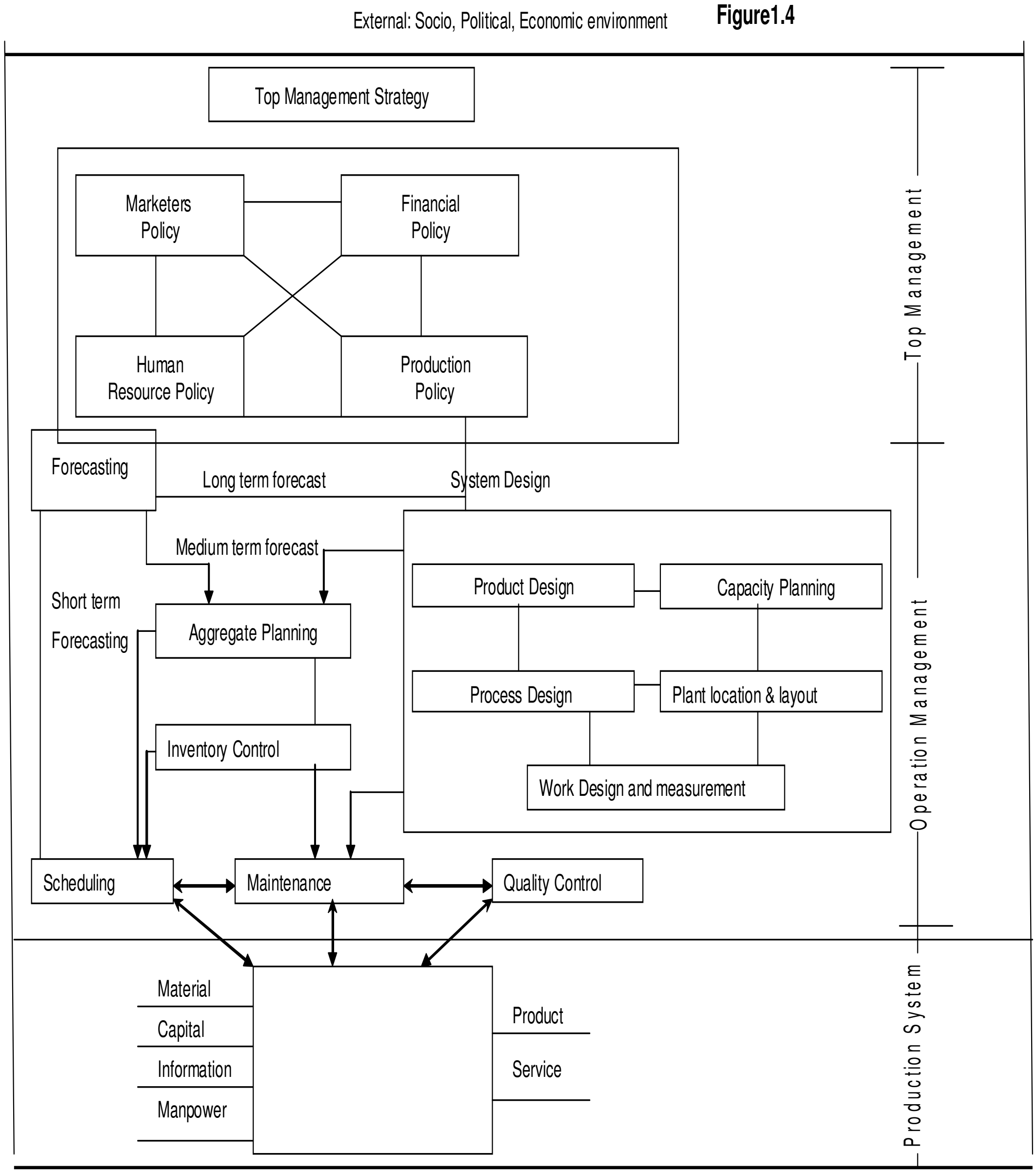
Figure 1.4- Communication in POM



1.7 COMPUTER INTEGRATED MANUFACTURING AND SERVICE SYSTEM

Computer Integrated Manufacturing (CIM), a strategic thrust, is an operating philosophy. Its objective is to achieve greater efficiencies within the business, across whole cycle of product design, manufacturing and marketing. International competition has intensified the requirement for high quality products that can compete in the global market place. As a result of this increased competition, the pace of development has been quickened and thus forcing manufacturers to enter into an era where the continuous

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quality improvement is maintained as a matter of survival, not simply being competitive As the time scale of product life cycle has decreased and the demand for the quality increased, attention has focused on improving the product quality and promoting the competitive ability of industries through better design, manufacturing, management and marketing.

Global manufacturing industry is now undergoing a rapid structural change. As this process is continuous, manufacturing industry is encountering difficulties as it confronts with a more changed and more competitive environment and also the market place. In order to share the international market, manufacturers need to implement two strategies. The first is, to improve the Enterprise Management. The second one is, to develop and apply a Systematic and Scientific Technology, i.e.., CIM.

With the rapid growth of the complexity of manufacturing process and the demand for high efficiency, greater flexibility, better product quality and lower cost, industrial practice has approached the more advanced level of automation. Nowadays, much attention has been given by both industry and academia to CIM.

Currently, most of the industries have highly automated facilities. To stimulate industrial companies for utilizing the newest manufacturing technology, this has compelled to develop a system architecture that does not only replace the existing manufacturing facilities, operational environments, but effectively utilizes the knowledge and facilities that are available in the industry.

To overcome the difficulties and solve the problems mentioned above automatic techniques and methodologies should be Introduced into real industrial manufacturing.

1.7.1 CIM Subsystems

Significant progress has been made in the manufacturing technology in recent years. Numerically control machine tools, automated material handling systems and controlled systems have been widely used in industrial companies. The Flexible Manufacturing System (FMS), Computer Integrated Manufacturing (CIM) or Systems or Automated Manufacturing Systems (AMS) can be attributed to and increasing number of companies. The advancing manufacturing and computer technology has brought new challenges to the designers of products, processes and system as well as to the managers. The traditional design and management tools can not effectively cope with problems arising in the modern manufacturing systems.

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1.7.2 Functional areas of CIM

CIM system has emerged as a result of the development in manufacturing and computer technology. The computer plays an important role integrating the following areas of CIM system.

- **Part (component) and product design**
- **Tool and fixture design**
- **Process planning**
- **Programming of numerically controlled (NC) machines, material handling system (MHS), etc.**
- **Production planning**
- **Machining**
- **Assembly**
- **Maintenance**
- **Quality control**
- **Inspection**
- **Storage and retrieval**

To emphasis the computer aspects, the terms **Computer Aided Design** (**CAD**), **Computer Aided Process Planning** (**CAPP**), **Computer Aided Manufacturing** (**CAM**), **Computer Aided Quality Control** (**CAQC**), Automatic **Storage Retrieval** (**ASR**), have used. Each term refers to one or more of the listed functional areas. **CAD** refers to the part and product design and tool and fixture design, **CAPP** refers to Process Planning, **CAM** refers to the programming of manufacturing hardware, production planning machining, assembly and maintenance, **CAQC** refers to the quality control and inspection and ASR involves the storage and retrieval of raw materials, finished products work in process inventory.

The computer plays a leading role in the automation and integration of hardware component i.e. machines, material handling carriers and the software components of manufacturing systems. In order to understand the CIM subsystems and the importance of integrating them, it is first necessary to explore the functional areas by these subsystems.

1.7.2.1 Computer Aided Production Planning

Production planning involves establishing production levels for a known length of time. This forms the basis for the following two functions:

1. Material requirement planning

2. Loading and scheduling

Based on the information regarding the type and quantity of parts or products to be manufactured, the materials required to produce the parts or products must be ordered with an appropriate lead time to ensure their availability for production. This function constitutes material requirement planning. Based on the material required, capacity- for example, machine hours and labor hours can be calculated.

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Machine loading involves assignment of parts and products to machines and machine cell in order to distribute the production loads. Scheduling determines the sequence in machines perform the operations.

1.7.2.2 Computer Aided Process Planning

Process planning for a part involves the preparation of a plan that outlines the routes, operations, machines and tools required to produce the component. Since the process is a tedious task, there has been a trend to automate it. As a result, a number systems have been developed. There are three basic approaches to the automated process planning. They are -

a. Variant Approach
b. Generative Approach
c. All based Approach

CIM Subsystems

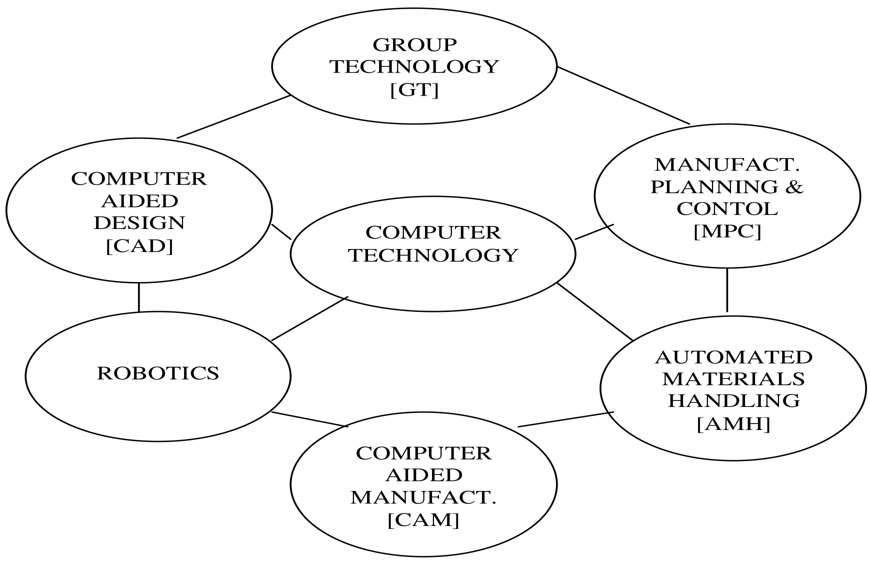
Intelligent Manufacturing

Development in artificial intelligence has had an impact on the manufacturing systems. All most all the areas of the computer integrated manufacturing have been effected by the artificial intelligence. Researchers and engineers are developing the intelligent systems ranging from application in machining and assembly to long term planning.

1.7.3 Conceptual framework of CIM

The conceptual framework of CIM is shown in Figure.1.6 are six major being integrated by computing technology. Note that one of these is Group Technology (GT).

Figure 1.6 – Conceptual framework of CIM



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According to Arthur D.Little and Co., GT is the important technology among the others and it will play a major role in the factory of the future. The GT concept is considered a center road towards a higher level of CIM.

1.7.4 Group Technology

Group technology (GT) is a concept that is currently attracting a lot of attention from the manufacturing community. GT offers a number of ways to improve productivity in the batch manufacturing. The essence of GT is to capitalize on similarities on recurring tasks. GT is, very simply, a philosophy to exploit similarities and achieve efficiencies grouping like problems.

1.7.4.1 Definition of GT

"Group technology is the realization that many problems are similar and that, by grouping similar problems, single solution can be found to a set of problems, thus saving time and effort"

1.7.4.2 History of GT

Prior to 1913, the era of Henry Ford and his model T, all machining models were similar to our present job shop techniques with machines laid out usually in lines or blocks of similar machines. The work was loaded onto the machines usually by the manual progress control system. Ford introduced the assembly line and that, in turn, led to automated transfer machines. However, the majority of engineering do not produce items in quantity that justify such methods and so the jobbing shop philosophy continued. GT is mainly a coordination of normal good engineering practices. It is impossible to say who first practiced GT. There are reports of it having been used in Germany in the 1930s.

In an international Conference held in Stockholm in 1947, the basic groups were explained by C.B.Nanthorst. In Italy M. Patrignany was an early exponent of this technology. However, little of this appears to have been in English. First published work was from the USSR by S.P.Mitrofanov in 1959 and there after subsequent books were published by F.S.Denyanyuk and E.K. Ivanov.The first reported work on GT outside Russia was done by a French Forges et Ateliers de Construction Electriques de Jeurmont - and this was about in Machinery in 1962. Subsequently, several British companies conducted considerable work in this field. There have also been considerable studies done by various consultants in the Universities. The significant contribution by J.L.Burbidge in the 1 960s led to GT as A total Manufacturing Philosophy.

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1.7.4.3 Advantages of GT

According to Burbidge, following are the advantages after introducing GT in manufacturing.

a. Short throughput times because machines are closed together.

b. Better quality because groups complete parts and the machines are closed together under one foreman.

c. Lower material handling costs because machines are closed together under one foreman.

d. Better accountability because machines complete parts. The foreman can be made responsible for costs, quality, and completion by due date.

e. Training for promotion for promotion since GT provides a line of succession, because a group is a mini-department.

f. Automation GT is a first evolutionary step in automation.

g. Reduced set up time since similar parts brought together on the same

h. Morale and job satisfaction since most workers prefer to work in groups.

Studies undertaken by N.L.Hyer indicate the following significant savings after implementing GT Snead prepared a summary matrix, listing the benefits listing benefits achieved for the various GT.

Table1.4 - Advantages of GT

Applications implemented set up time	20-60%
Planned labor	15-25%
Tooling	20-30%
Rework & scrap	15-75%
Machine tool expenditures	15-75%
WIP carrying costs	20-50%

1.7.4.4 Organizational suitability for GT

The suitability of a firm for the introduction of GT depends on several factors. The survey of Willey and Dale give a tentative description of a company profile likely to achieve the greatest benefits from GT, some of these are:

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a. The company must be a relatively small organization with a reasonably small machine tools, and manufacturing equipment.

b. The company should not be typified by either large or small component variety.

c. The batch sizes and the batch size range of products of the companies it is relatively small.

Athersmith and Crookall Rajagopal and Smith Gupta Andand Grayson have suggested another way of finding out the suitability of GT for a batch production industry. Computer simulation has been used by the effect of introduction of GT in the batch production industries based on the parameters such as throughput time, WIP inventory and plant utilization Further GT is considered a desirable stepping stone for establishing Just-In-Time production.

1.7.4.5 Group Technology in CIM

One may question whether a cellular concept is applicable to CIM systems. Some studies have shown that grouping machines to machine cells may limit the manufacturing system flexibility. However, industrial applications have proven that it is virtually impossible to implement a large scale CIM subsystem using a cellular concept. Here after, the automated manufacturing systems that cellular approach can be called as, Cellular Automated Manufacturing (CAMS). Four crucial factors of CAMS as identified by Kusiak are:

1. Volume of information

Volume of information a large-scale CIM subsystem is typically large, and it is too expensive to effectively process information without the system's decomposition.

2. Material handling system

In a typical CIM subsystem, automated material handling carriers are used (AGVs and Robots). Each of the two carriers can tend a limited number of machines.

3. Technology Requirement

Some machines have to be grouped together due to technological requirements. For example, a forging machine and a heat treatment section.

4. Management

Although in most of the currently CIM subsystems, the degree of automation is higher than in classical manufacturing systems, humans will be, for a long time, an integral

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part of these new manufacturing systems. Due to limited size of each machine cell, a CAMS is easier to manage than the entire system.

Review Question:

Following stands for :

1. CRM 2. FMS 3. AMS
4. AS/RS 5. CAD 6. GT

1.8 GLOBAL SUPPLY CHAIN

Even though the countries fought for border issues, but there is no trade barrier for the trade is concerned. GATT agreements and WTO paves the way for the **Global Supply Chain in trading.** (See Figure1.7).

Overall Objective of Global Supply

The objective of global supply chain configuration is in meeting or exceeding worldwide customer (internal and/or external) expectations at the lowest cost.

Specific Objectives and Expectations of Global Supply

Achievement of the transformation of supply chains into value chains will normally include some combination of the following objectives and expectations:

- Leverage spend (across business units and geographic boundaries).
- Align Incentives for integration of activities (buyers, suppliers, end-users) to support organizational goals and strategies.
- Optimize supply chain operation (no. of members, capabilities, costs).
- Reduce inventories across the chain.
- Reduce all costs (item costs and supply chain operational costs).
- Assurance of supply of right quality items to support operations.

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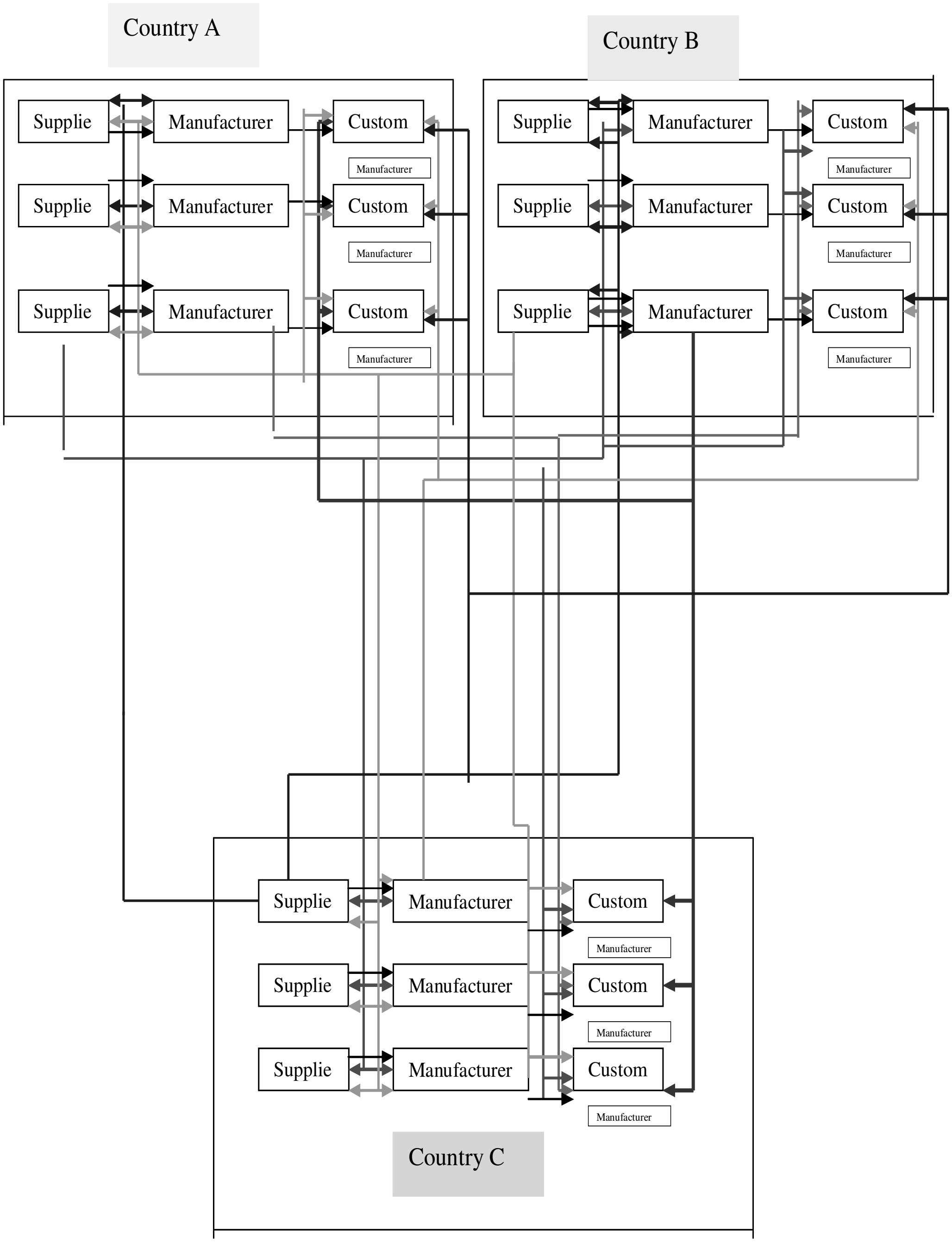
Figure 1.7- Global Supply Chain in trading



For simplicity only one supplier, manufacturer and customer of each country is taken in the above diagram, same can be possible for others.

1.8.1 Global Complexities

If the supply/value chain involves sourcing in multiple countries, additional considerations need to be addressed. Some of these include:

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- Currency exchange and risk.
- Counter trade opportunities and requirements.
- Varying laws and jurisdictional questions.
- Cultural differences.
- Language differences.
- Labor and training availability, practices, laws, regulations.
- Transportation, packing, shipping, storing, import, export, customs.
- Security: materials, products, personnel, intellectual property.

Challenges and Barriers to Transforming Global Supply Chains into Value Chains

In the varying environments encountered internationally, there are a number of challenges and barriers involved in building global supply chains. Many of these are rarely concerned with the domestic supply chains. Some of these include:

- Uncertain political stability, self-serving governments.
- Lack of infrastructure in some countries (roads, port facilities, trained labor, utilities, communications).
- Lack of critical market mass in particular countries.
- High transaction costs.
- Requirements to use in-country agents or partners and local content requirements.
- Lack of potential for repeat purchases.
- Slower adoption of e-business than in the domestic market.
- No or limited free trade zone availability.
- Partner/contract limitations requiring bidding for all procurement activities and alliance-building.
- High logistics and transportation costs.
- Different time zones (communication difficulties).
- Financial risks are higher, e.g. potential for war, terrorism, government changes.
- The nature of global activity (may be fragmented and/or scattered).
- Long/unpredictable supplier lead times.
- Protectionism (tariffs, duties, quotas, inspections).
- Limited number of qualified global suppliers.
- Difficult to link global project work to "run and maintain" global activities.
- Limited availability of trained personnel for purchasing or supply management positions inhibiting.

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1.8.2 How to Transform Global Supply Chains

Improve the quality/cost ratio of your supply chain. Strive for the highest quality at the lowest cost.

Leverage value across the supply chain

Understand what constitutes value and to whom it is valuable in your supply chain. Identify and evaluate trade-offs between value added and profitability. Leverage knowledge to create and deliver the value. Where commodity markets are involved, be proactive in initiating change that will benefit you.

Redefine the boundaries of business

Redefine the boundaries of your business in the context of what provides continuing competitor and customer advantage. Evaluate any existing vertical integration structures and replace with virtual sourcing if value can be added by doing so. Evaluate what to insource and what to outsource. Use all capabilities of existing or potential supply chains in the development of new products.

Develop relational competence

View relationships with other members of your supply chains as a continuum ranging from spot relationships to strategic alliance or co-ownership but recognizing that most relationships will be somewhere between these extremes. Determine where more competition will add value and where more collaboration will add value and seek the best combination of competition and collaboration.

Manage at the right level

Determine which strategies and activities best add value with global management and which best add value with local management. Determine the best level of autonomy for local management within supply chain activities. Analyze supply chains for each category of material or service that is significant to the organization to determine the best value -adding approach for management and control.

Develop supply chain responsiveness

Determine how the degree of responsiveness to customer needs such as re-supply time or product mix adjustment matches with customer requirements in each such area. Consider techniques such as supplier managed inventory, supplier integration,

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and consignment stocking. Pay particular attention to the quality of demand forecasts throughout the supply chain. Drive down purchase costs. Capture cost saving opportunities and share benefits with contributing supply chain members. Pay attention to the differing cost management and purchase strategy needs of various categories of purchases. For example, commodities, specialty items, custom-made items, MRO materials. Service purchases can be similar.

Bring About Change

Change Management 1-1. It refers to transforming supply chains which involves a collateral change management. Consider purchases in the broadest possible sense - do not exclude anything which is purchased by the organization, material or service effort. This includes the following activities:

~ Seek Top Management mandate with visible support.
~ Identify the local sponsors and supporters of the supply chain, change early in the transformation process.
~ Use coordinated communication efforts to develop a dialog about the benefits and obstacles for implementation.
~ Target quick wins and immediate opportunities.
~ Focus on overcoming obstacles to implementation by creating a cross functional approach (Team) to address issues.
~ Perform a competitive advantage review in order to leverage the core competencies of the supply chain members .
~ Develop a supply chain agenda, manage the overall program and frame goals to address major gaps in supply chain performance.
~ Develop a business plan that will integrate the activities of the supply chain members.
~ Formulate key performance metrics and measurements, tracking quarterly.
~ Review results and make modifications as necessary to achieve supply chain optimization.

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Summary

- This unit helps the reader to understand the importance of the production / operation system in an organization.
- Characteristics of the different production / operation system are detailed out in addition to when one should prefer what type of system.
- The components of computer integrated manufacturing system and the introduction of Global supply chain network are highlighted.

Review Questions:

1. State any five Global Complexity.
2. Give any three steps to develop Global Value Chain?

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UNIT II

MATERIAL AND INVENTORY MANAGEMENT

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2.5.1 Problems of Conventional Production System
2.5.2 Conventional vs. JIT attributes
2.5.3 JIT as a waste elimination tool
2.5.4 KANBAN production control system
2.5.4.1 Working of KANBAN
2.5.5 Uniform loading
2.5.6 Quality Control
2.6 ABC analysis
2.6.1 Kind of Control

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UNIT - II

MATERIAL AND INVENTORY MANAGEMENT

2.1 INTRODUCTION

In this unit the productivity of material resources is discussed. The role of materials management in an organization and the latest material handling devices like Automated Guided Vehicle (AGV), Automatic Storage and Retrieval System (AS / RS) and Robots are illustrated. The deterministic and probabilistic inventory models are illustrated with examples. Detailed discussions are carried out about material requirement planning and manufacturing resource planning. The evolution of ERP system is dealt. In addition, introduction about e-business and e-operation strategies are also explained.

2.2 LEARNING OBJECTIVES

- To know the importance of material resources.
- To understand functions of materials management.
- To understand the computer controlled material handling devices.
- To know the importance of deterministic and probabilistic inventory models.
- To know the working of MRP – I and MRP – II systems.
- To highlight the E-business and e-operation strategies.

2.3 MATERIAL MANAGEMENT

2.3.1 Definition and Scope

We can define Materials Management 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.

2.3.2 Objectives

However, within the broader management objectives of any industry or business, Materials Management’s contribution towards objectives may be divided into two categories:

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1) Primary and

2) Secondary.

The former contributes directly to the Materials Management function and the latter, helps other departments to achieve their objectives.

2.3.2.1 Primary Objectives

Purchasing:

Materials play a vital part in the field of cost-control and operating expenditure of any organization and therefore, materials have a direct bearing on the cost of a product, manufactured. If the Materials Department can reduce the overall materials cost through an efficient system of buying, it can directly contribute its share to the enhancement of profit. Thus lower prices, lower procurement and possession costs are important objectives of Materials Management. Price consciousness or less materials cost means more profit as embodied in the phrase, "Purchasing for Profit" which is readily recognized by Management. It is therefore a prime functional responsibility of the Materials Management department.

Stores and inventory management:

Arriving at the right balancing point in the inventory investment like investment in any other capital assets has always been a perplexing problem to industries. Inventory Management function is more complex, more subtle and the balance of costs and gains is much more difficult to find out. Briefly, Materials Management objective here is to have the correct quantity and right quality of material on hand at the time required with a minimum of investment expenditure, consistent with business experience. When inventory turnover is high, storage and carrying costs are low.

Continuity of supply:

This is an other important objective of Materials Management. Specially in automated processes, where costs are rigid and are not easily amenable to reduction due to lack of production materials, the question of continuity of supply gains prominence. This foreshadows all other objectives, because idle-time costs of men and machines push up overall costs of production and expediting supply means additional transport costs.

Quality of materials:

Where quality of materials presents cost plus production engineering problems, it may well become one of the prime objectives of Materials Management, where other objectives are sacrificed at quality-cost.

Good supplier relations:

A good supplier relation, on which depends much of the product-reputation of the company, is also one of the key objectives of Materials Managers. Suppliers respond

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to fair treatment but are uncooperative and unwilling if indifferently treated. The Materials Management department can improve relations by providing the required stimuli for their better performance.

2.3.2.2 Secondary Objectives

Secondary objectives are so varied that they limit the possibility of listing exclusively in one breath. In one way or the other, they help to achieve the primary objectives, but different organizations put different emphasis on them. The following are a few examples.

Make-or-Buy decisions:

Since the Materials Management department is immediately concerned with the selection of supply sources, materials-cost, procurement-cost and the availability of materials. it influences heavily the Make-or-Buy decision. Often, this is a Committee action where other departments are also involved. However, the Materials' department's contribution is still substantial and more direct.

Value analysis and Value engineering:

Any item that is produced or bought is to serve a specific purpose. Before making or buying any material or equipment, engineers and buyers must decide what purpose they are to serve in order to find out whether a lower-cost design would work well or a less costly item could fill the need. Both engineering department and purchase department may watch the specifications for the best value of the money spent.

'Value engineering' and Value Analysis' are close to the same thing. They are approaches to cost-saving goals that deal primarily with product design. The first usually refers to what the engineering department is doing in this direction and the second usually refers to the work that the buyer is doing in this area. If value analysis is designed to reduce the cost of an item, standardization may often eliminate the item entirely.

Standardization:

Standardization is essential to a mass production system which is defined as "that which has been established as a model to which an object or action can be compared". However, one should take note that even when a substitute is technically feasible, it is not always economical to use it. The economics of standardization is not necessarily so complex.

All that is required is to compare costs of acquisition and carrying before the substitution was made with the costs after it was made. A standardized program is primarily designed to root out unneeded inventories. The buyer who knows who made the original components, need not pay a premium price for it to another equipment manufacturer for the same thing.

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The Engineering department is primarily responsible for standards and specifications. However, the Materials department can promote incorporation of standard components into product design to reduce cost. The fewer the items that need be managed, the simpler and more efficient is the Materials Management process, so that the Materials Management department can periodically review the stock to suggest weeding out of non-standard items.

Product development and new products:

Since the discovery and improvement of materials frequently lead to a new product and lower costs on existing products, the Materials department can suggest materials and components that will do better or equivalent jobs at lower cost. Product efficiency is basically a compromise between engineering design and economic objective of Management. The Materials Manager's economic knowledge can supplement the technical skill of engineering through a product change for bigger profits. Again, a program designed to find ways and means of utilizing the by-products or wastes is always profitable and here the Materials department can render substantial help by adding new products to the existing product-line.

Price, demand and requirements forecasting:

In large concerns this is a functional responsibility of economists. They make forecasts both for sales and purchases. Materials Management personnel translate them into specific purchase actions. Because of their intimate knowledge of the market conditions through daily contacts with suppliers, in medium or small-size organizations, Materials Management departments do this job. By analyzing and interpreting data of past sales, seasonal variations in prices, availability and demand for materials, they forecast future trends and plan material requirements accordingly.

An organization structure is an essential tool of management:

As a system of responsibility and of formal interrelations, it is concerned with two of the elements, namely, planning and coordination. Its chief purpose is to ensure smooth and balanced working of the organization. Obviously the size of the unit must affect the way in which management and other activities are carried out. Clearly, a large organization will be able to use and will need to use techniques and procedures of a different kind and higher degree of complexity than those of the medium or smaller firm. In other words, there will be differences in methods or routines according to differences in size, but the fundamental principles of management and the approach necessary for the attainment of effective management are the same, irrespective of size.

1. The determination of the basic objectives:

The basic objectives of an organization determine the organization structure for they determine the type, stability, structure and permanency of the organization. The

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objectives of an organization play, therefore, a vital part in determining how quickly the structure should be developed, what it should look like, its operating cost and permanency. What we want to accomplish should be kept clearly in mind while determining and setting up its structure. Obviously, the organization structure of a large corporation is much more complex, and therefore, slowly developed. Here too, objectives affect the structure. Once the objectives are clearly determined, the development of structure will follow the natural path dictated by the desire to reach these objectives. An organization structure should never hinder the achievement of these objectives; instead it should facilitate the mechanism that will enable the organization to accomplish things more easily and effectively than when left in unorganized things more easily and effectively than when left in an unorganized fashion. Thus, if it is decided that the company should add to a new line of product, and therefore, expand its marketing territory, such an objective and its concomitant Materials Management activities would necessarily affect the final structure of the organization.

2. Determination of the areas of activity:

Organization itself is nothing but the application of the universal law of specialization. Through organization, a person's actions and responsibilities are narrowed to one or a few functions, specializing in these few and thereby, increasing efficiency.

Specialization by division of work into functional areas enables one to understand his job more thoroughly. Therefore, effective organization must include specialization as an element of efficiency for the performance of one or a very few leading functions. As far as possible, similar functions should be combined into one position. Although its advantages are universally recognized, yet it has its limits which should not be exceeded.

3. Determination of the ideal structure to accomplish the desired activities:

Physical listing of activities will in itself suggest possible areas within which it needs to consolidate work. Each of the groupings will then lead to an 'ideal' organization structure to carry out the functions. Products, tools and processes may be considered as possible areas of functional activities. This 'ideal' structure may then represent the long range or ultimate organization with available personnel, funds, etc., so as to reconcile the 'ideal' with the 'working' organization.

4. Authority and Responsibility:

Authority is the right to give orders and the power to exact obedience. Authority is not to be conceived apart from responsibility, that is, apart from sanction – reward or penalty, which goes with the exercise of that power. Delegation of authority is the key point of organization. Without delegation there would be no organization and this is the core of all formal processes of organization. A major task of top management is the delegation of authority to proper individuals in order to secure appropriate actions. But often, we hear of responsibility being delegated without power to command or act.

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Such an organization set-up makes for ease and efficiency in determining responsibility and delegating necessary authority. Since it would not be just to hold a person responsible for performance of a task without first giving him the authority, responsibility should always be coupled with commensurate authority. Here, authority can be delegated, responsibility cannot.

5. Span of Control:

By span of control, we mean the number of individuals one supervises and directs. There is a definite limit to this number and this, to a great extent, determines the units of an organization. There may be a tendency to over supervise and this may, in effect, mean scant or ineffective supervision.

On the other hand, when too few report to one supervisor, his time is not effectively used. However, no hard and fast rule can be established and it depends upon the type of work performed.

6. Personal Ability:

Simply assigning jobs to individuals does not mean that they will be accomplished. Individuals differ in capacity and ability and these differences as well as personal limitations should be considered before placing an individual in an organization. In developing an organization, therefore, proper regard should be paid to the personal ability of individuals assigned to various components. An organization is referred to the people and its structure reflects the ability of its members which again largely determines the structure.

7. Unity of Command:

For any action whatsoever, an employee should receive orders from one superior only. Such is the rule of unity of command. No one in any organization should report to more than one line supervisor and everyone should know to whom he reports and who reports to him. In fact, receiving directions from more than one individual may easily result in confusion, conflict, lack of action and poor morale. Each member of an organization, therefore, should receive directions from only one boss, his immediate superior and should be responsible to him alone.

8. Job Assignment:

Logical groupings or related functions should be made in developing the organization structure. It is often desirable to have the responsibility for each of these functions assigned to specific individuals with these persons turning to the leader charged with the accomplishment of the overall function.

9. Regulations:

Rules and regulations aid improper operation of an enterprise. A complete statement of the operating objective of an enterprise as well as the responsibility and

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the authority of each individual should be formulated and should be made available in writing to all personnel in the organization. They may be broad and specific. Even detailed methods manuals to describe how the tasks are to be carried out may be valuable. They define the authority which certain individuals have over particular functions.

10. Two way communication:

Despite the fact that line of authority provides channels downward and upward, they are often used only to pass directives downward and never as a means of communicating attitudes, feelings or ideas upward. Such blocks in communication occur in a great many organizations. In fact, one of the most immediate and costly results of poor organization is the breakdown of intra-organizational communication. In as much as an organization is developed to aid in accomplishing an objective, good communication is necessary if all employees are to know what to do to reach this objective.

11. Flexibility:

The environment in which an organization exists and the individuals who make it up are constantly changing. Organizations change because of technological, economic or personnel changes or changes in the objectives. An organization possessing flexibility withstands minor pressures, but gives way to the demand for genuine change permitting their expansion or contraction without seriously altering the basic functions of various segments of the structure.

12. Line and Staff activity:

Line and staff functions should not be combined in one individual where separation of functions is possible. Line functions, as has been said before, are those which directly affect the product or service. Staff functions are those that aid the line or, are auxiliary to the line function. Because confusion may result, line and staff functions should be separate wherever possible. Staff specialists are useful and there will always be a need for them. Especially in large materials organizations, where materials management is treated as an integrated activity, there should be less need for staff experts in a variety of functions. Among the major staff services value analysis, economic forecasting and administrative planning may be essential. A staff expert on 'trade relations' is also a common feature in large-scale industrial purchasing.

Leadership Question:

Leadership is obviously more than personal ability and skill. Leadership is important to the effective set up and operation of every organization because leadership is the one force that charts and makes possible the economic accomplishment of the objectives. A 'weak' organization structure with effective leaders will probably accomplish more than a so called 'strong' organization with weak leaders.

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Structural balance:

An organization conceived and developed along the principles detailed above, will more than reward its leaders, as well as its members. In the process of forming a new organization structure or of reorganizing an existing one, these principles should be considered. But the consideration of these principles, rules and types will not in itself result in the development of a new organization. Instead a new organization structure must be visualized and developed step by step. Although no series of rules can assure an effective organization, this objective can be approached in a systematic fashion without much difficulty. In a balanced organization, each function of the structure should be large enough, but not overly developed in relation to other functions of the organization. Without such a balance, the objective of the organization cannot be achieved economically.

Review Questions:

1. List any two Primary functions.
2. List any two Secondary functions.

2.4 MATERIAL HANDLING

2.4.1 Introduction

For an ideal operation system, material handling is not a desirable activity. The reason is it does not add any value to the product but it adds only cost to the product. So when you design a layout you should see that the movement of materials should be minimum. The material handling equipment used mostly depends upon the type of production system to be adopted. In the case of flow line production system, the following material handling equipments are used.

Conveyors

1. Slat conveyor
2. Pusher bar conveyor
3. Roller conveyor
4. Belt conveyor
5. Wheel conveyor
6. Screw conveyor
7. Pivoted bucket conveyor
8. Apron conveyor
9. Spiral chute
10. Pneumatic conveyor
11. Trolley conveyor

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In the case of **job order/intermittent type production systems**, the material handling equipment used are

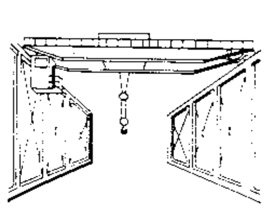
1. Fork Truck
2. Platform Truck
3. Industrial Truck
4. Straddle carrier
5. Hand operated vehicles

In addition, CRANES and HOISTS are also used in the production system. Thus is not specifically related to particular system. All types of production system uses/this kind of material handling equipment.

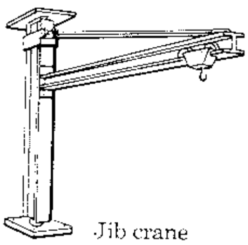
The types of CRANES and HOISTS are :

1. Overhead traveling bridge cranes
2. Jib crane
3. Gantry crane
4. Air hoist
5. Electric Hoist
6. Chain hoist

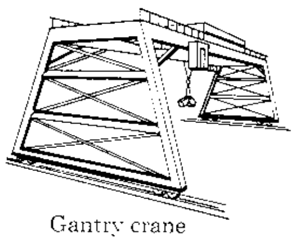
There is no hard and fast rule that particular material handling system used only by the particular production system. But you can find that the trucks used in the flow line. Production as well as the conveyors used in the job order and intermitted production system.



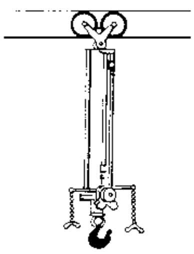
Bridge crane



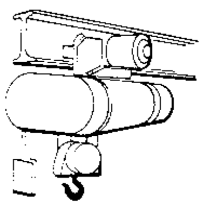
Jib crane



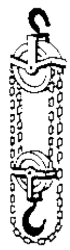
Gantry crane



Air hoist



Electric hoist



Chain hoist

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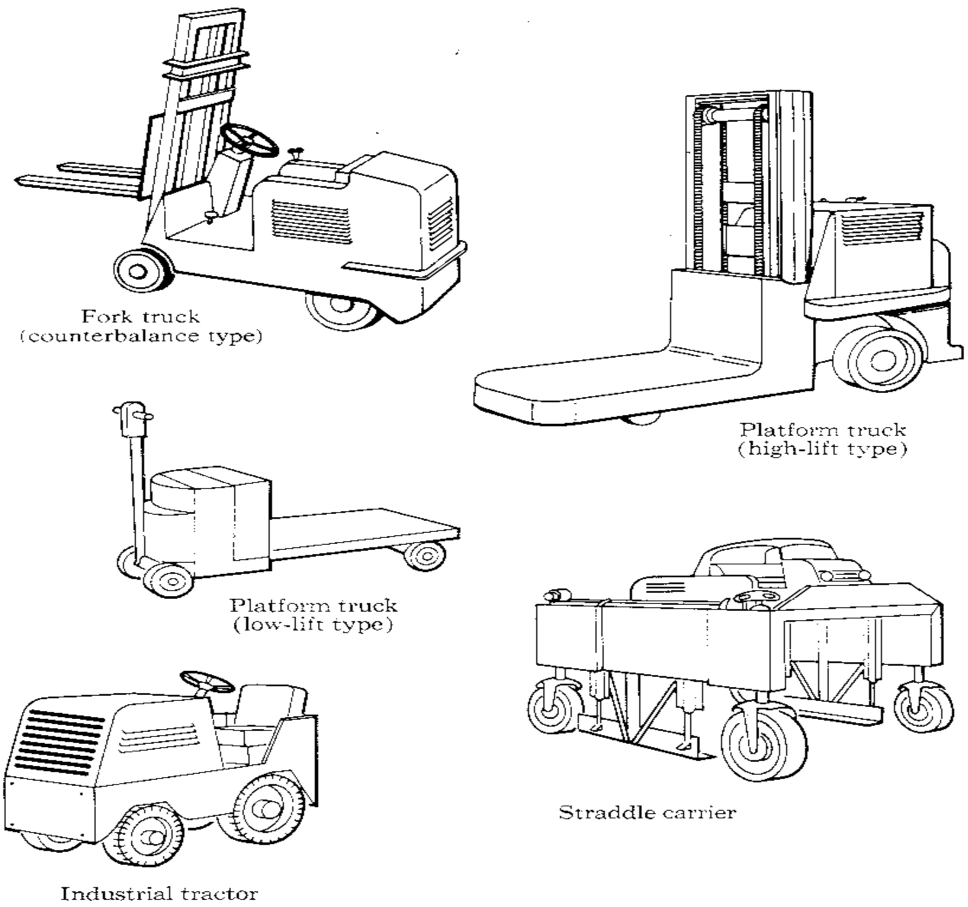
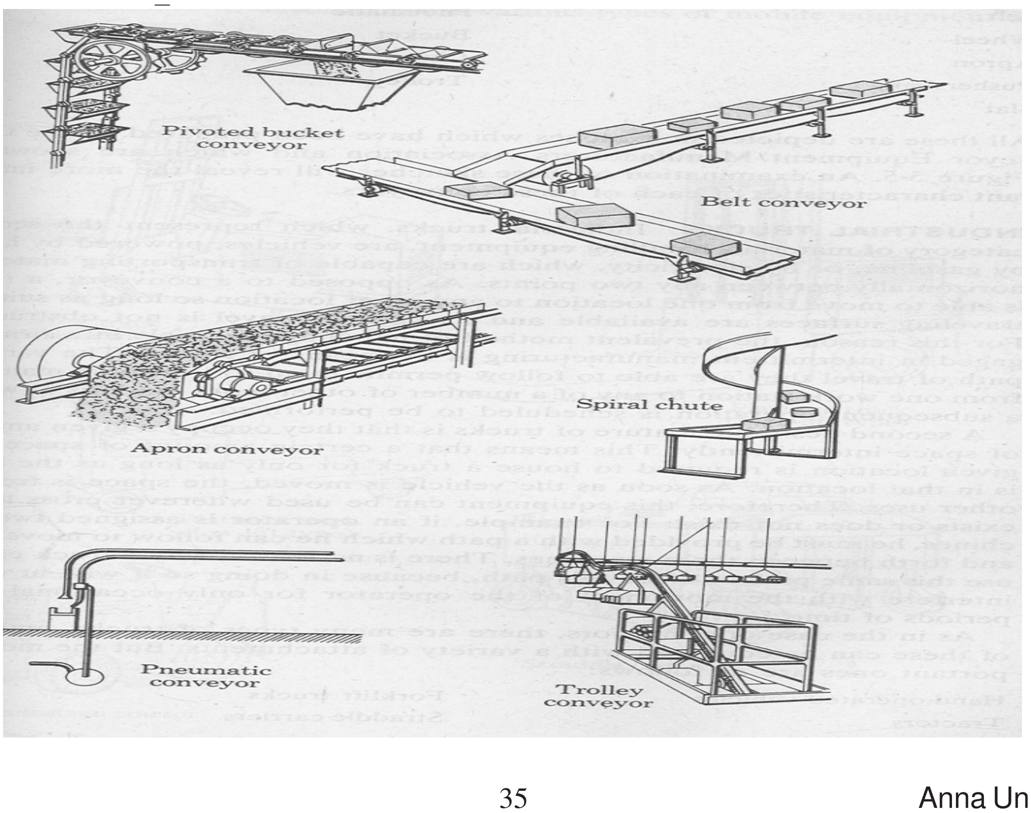

Fork truck
(counterbalance type)
Platform truck
(high-lift type)
Platform truck
(low-lift type)
Straddle carrier
Industrial tractor


Pivoted bucket
conveyor
Belt conveyor
Apron conveyor
Spiral chute
Pneumatic
conveyor
Trolley
conveyor

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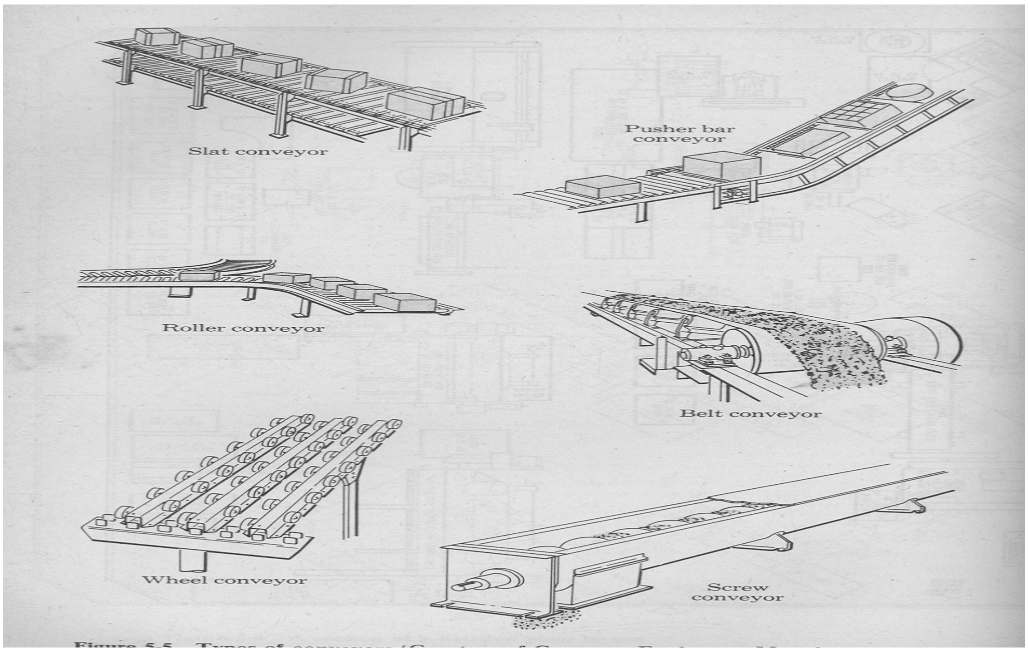

2.4.2 Robot

The word “robot” is also used in a general sense to mean any machine that mimics the actions of a human, in the physical sense or in the mental sense. It comes from the word *robota*, labor or work. The word robot first appeared in Karel Capek’s science fiction play R.U.R. (Rossum’s Universal Robots) in 1921. The word was brought into popular Western use by famous science fiction writer Isaac Asimov.

A robot is an electro-mechanical or bio-mechanical device or group of devices that can perform autonomous or preprogrammed tasks. A robot may act under the direct control of a human or autonomously under the control of a programmed computer. Robots may be used to perform tasks that are too dangerous or difficult for humans to implement directly, such as radioactive waste clean-up, or may be used to automate mindless repetitive tasks that should be performed with more precision by a robot than by a human, such as automobile production. Robot can also be used to describe an intelligent mechanical device in the form of a human, a humanoid robot.

The word robot is used to refer to a wide range of machines, the common feature of which is that they are all capable of movement and can be used to perform physical tasks. Robots take on many different forms, ranging from humanoid, which mimic the human form and way of moving, to industrial, whose appearance is dictated by the function they are to perform.

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Asimov proposed three ‘laws’ which for many years were recognized as principles in the use of robotics:

A robot must not harm a human being or, through inaction, allow a human to come to harm.

A robot must always obey human beings unless this is in conflict with the first law.

A robot must protect itself from harm unless this is in conflict with the first or second law.

Robots can be grouped generally
Mobile robots (e.g. autonomous vehicles)
Manipulator robots (e.g. industrial robots)
Self reconfigurable robots, which can conform themselves to the task at hand.

An industrial robot has been defined as:

“A reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks”.

The definition says the robot is a reprogrammable and multifunctional. The reprogrammability means, through computer the programmed instructions can be written fed and also can be edited. Multifunctional is in the sense of its versatility. It can perform various activities.

2.4.2.1 Advantages of Robots in Industry:

We can analyze the various advantages of robots in three perspectives.

Technical factors:

When comparing robot and human performance it is generally considered that humans cannot match the speed, quality, reliability, endurance and predictability of robotics systems. However, robots cannot compete with hard automation if the cycle times are short and flexibility is not an important factor. Robots therefore provide a link between the rigidity of dedicated automation and the flexibility of the human operator, in that they offer:

High flexibility of product type and variation.
Lower preparation time than hard automation.
Better product quality.
Fewer rejects and less waste than labor-intensive production.

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Economic factors:

Major factors in considering the possible implementation of robotics systems include:

- The need to increase production rates to remain competitive.
- Pressure from the marketplace to improve quality.
- Increasing costs.
- Shortage of skilled labor.

In general, robotics can increase profitability by:

- Providing maximum utilization of capital-intensive production facilities for up to 24 hours per day, seven days per week;
- Reducing production losses due to absenteeism and skilled labor shortage, reducing the amount of inventory which is being processed with resulting savings in work in progress.
- Reducing the manufacturing lead time of the product or processes;
- Reducing scrap and increasing product quality, with resulting reduction in the number of customer complaints.

Social factors:

- Robots are employed to do mindless, repetitive tasks so that the human capital can be utilizied in more interesting work.
- Many low-level tasks can be carried out by robots.
- Robots can be utilized to perform undesirable work in dangerous or hazardous environments and work requiring heavy physical effort.

  E.g.: spot-welding car bodies, applying spray paint.

- Robots are successfully implemented in the nuclear industry for carrying out the maintenance work on reactors and for the handling of dangerous waste products.

2.4.2.2 Components of a robot:

A robot has many components which include:

A *base*- fixed or mobile.

A *manipulator* with several degrees of freedom (DOF).
An *end-effector or gripper* for holding a part or a tool.
Drives or actuators causing the manipulator arm or end-effector move in a space.
Controller with hardware and software support for giving commands to drivers
Sensors to feed back the information for subsequent actions of the arm as well as to interact with the environment in which the robot is working.
Interfaces connecting the robotic subsystems to the external world.

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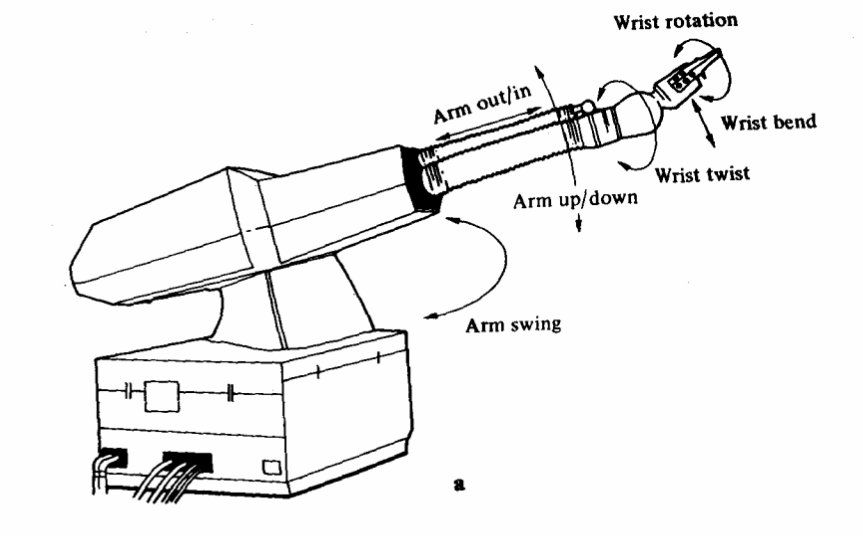
Figure 2.2 – Movements of a Robot



2.4.2.3 Industrial applications of robotics:

Material handling:

Depalletizing/palletizing
Transporting components
Transfer of components/tools
Bottle loading
Parts handling

Machine loading and unloading components:

Loading parts to CNC machine tool
Loading a punch press
Loading a die casting machine
Loading electron beam welding and laser beam welding machines
Loading/orientating parts to transfer machines
Spray painting
Loading parts on the test machine
Painting of trucks/automobiles
Painting of agricultural equipment
Painting of appliance components
Arc welding
Spot welding
Arc welding
Seam welding of variable width
Machining
Drilling

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Deburring
Sanding
Grinding
Cutting
Forming
Assembly
Mating components
Riveting small assemblies
Inspection
In-process measuring and quality control, searching the missing parts
Others
Heat-treatment, applications of adhesives etc.

2.4.2.4 Applications of robotics in other fields:

1. Hazardous environments

Mining
Exploration
Search and rescue
Tunneling for main roadways
Operations in short passages
Municipal services

Fire fighting
Underground (dangerous gas-filled)
Sewer clearing
Maintenance of atomic reactors
Space
Space vehicles
Undersea
Oil/mineral exploration
Salvage operations

2. Medical
Rehabilitation engineering for handicapped
Non-invasive diagnostics
Surgery

3. Distribution
Warehousing
Retailing (for food industry or for retail industry)

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4. Agriculture

5. Hobby/household purposes

6. Military applications of robots may be in both manufacturing and non-manufacturing areas.

2.4.2.5 Dangers and disadvantages:

Although robots have not developed to the stage where they pose any threat or danger to society, fears and concerns about robots have been repeatedly expressed in a wide range of books and films. The principal theme is the robots' intelligence and ability to act could exceed that of humans that they could develop a conscience and a motivation to take over or destroy the human race.

Currently, malicious programming or unsafe use of robots may be the biggest danger. Although industrial robots may be smaller and less powerful than other industrial machines, they are just as capable of inflicting severe injury on humans. However, since a robot can be programmed to move in different trajectories depending on its task, its movement can be unpredictable for a person standing in its reach. Therefore, most industrial robots operate inside a security fence which separates them from human workers.

Even without malicious programming, a robot, especially a future model moving freely in a human environment, is potentially dangerous because of its large moving masses, powerful actuators and unpredictably complex behavior.

Designing and programming robots to be intrinsically safe and exhibit safe behavior in a human environment is one of the great challenge in robotics. Some people suggest that developing a robot with a conscience may be helpful in this regard.

2.4.3 Automated Storage and Retrieval System (AS/RS)

An integrated FMS, AGVS, and AS/RS system provides an efficient and effective production system for manufacturing. Receiving, identification and sorting, dispatching, placing in storage, retrieving from storage, packing, shipping, and record keeping have traditionally been considered the functions of storage systems. An AS/RS attempts to achieve these functions by automating most of these procedures in a cost-effective and efficient manner.

An automated storage and retrieval system is defined as:

A combination of equipment and controls, which handles, stores and retrieves materials with precision, accuracy and speed under a defined degree of automation.

Different operations of AS/RS:

- Automatic removal of an item from a storage location
- Transportation of this item to a specific processing or interface point

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- Automatic storage of an item in a predetermined location, having received an item from a processing or interface point.

An automated storage and retrieval system comprises the following:

- A series of storage aisles having storage racks.
- Storage and retrieval (SIR) machines, normally one machine per aisle, to store and retrieve materials
- One or more pickup and delivery stations where materials are delivered for entry to the system and materials are picked up from the system.

2.4.3.1 Types of AS/RS

Several types of AS/RSs are distinguished based on certain features and applications.

Some of the important categories include:

1. Unit load
2. Miniload
3. Person-on-board
4. Deep-lane
5. Automated item retrieval system

1. Unit Load AS/RS

The unit load AS/RS is used to store and retrieve loads that are palletized or stored in standard-size containers. In general, a unit load system is computer controlled; having automated machines designed to handle unit load containers. Each machine is guided by rails in the floor. These are the load-supporting mechanisms that moves loads to and from storage locations and the pickup-and-deposit stations.

2. Miniload AS/RS:

A miniload system is designed to handle small loads such as individual parts, tools, and supplies. The system is suitable for use where there is a limit on the amount of space that can be utilized and where the volume is too low for a full-scale unit load system and too high for a manual system. A smaller investment and flexibility of handling small items make it a popular choice in industry.

3. Person-on-Board Systems

The person-on-board system allows storage of items in less than unit load quantities. A person rides on a platform with the S/R machine to pick up individual items from a bin or drawer. This provides in-aisle order-picking ability, which can reduce the time it takes to fill an order. The operator can select the items and place them in a tote or module, which is then carried by the S/R machine to the end of the aisle or to a conveyor to reach its destination.

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4. Deep-Lane AS/RS:

The deep-lane AS/RS is another variation on the unit load system. The items are stored in multideep storage with up to 10 items per row rather than single or double deep. This leads to a high density of stored items, permitting high usage of the unit.

Each rack permits flow-through of items; that is, an item is deposited on one side of the storage rack and removed from the other side. The S/R machine is similar to the unit load S/R machine, except that S/R machines have specialized functions such as controlling rack-entry vehicles.

5. Automated Item Retrieval System:

This system is designed for automatic retrieval of individual items or cases for storage. The storage system consists of items stored individually in a flow-through system that can be automatically released from storage and automatically brought to a required point. The items are stored from the rear, as in the deep-lane system, and are retrieved from the front.

2.4.3.2 Technical and Economic Benefits of AS/RS

There are several benefits of AS/RS for an organization, which include:

- An AS/RS is highly space efficient. Space now occupied by raw stock, work in process, or finished parts and assemblies can be released for valuable manufacturing space.
- Increased storage capacity to meet long-range plans.
- Improved inventory management and control.
- Quick response time to locate, store, and retrieve items.
- Reduced shortages of inventory items due to real-time information and control.
- Reduced labor costs due to automation.
- Improved stock rotation.
- Improved security and reduced pilferage because of closed storage area.
- Flexibility in design to accommodate a wide variety of loads.
- Flexibility in interfacing with other systems such as AGVS, FMS, and inspection systems such as coordinate measuring machines.
- Reduced scrap and rework due to automatic handling of parts.
- Reduced operating expenses for light, power, and heat.
- Helps implement just-in-time (JIT) concepts by getting the right parts, tools, pallets, and fixtures to the right place at the right time because of automatic control of storage and retrieval functions and accurate inventory management.

NOTES

2.4.4 Automated Guided Vehicle

Automated Guided Vehicles (AGV), popularly known as battery-powered driverless vehicles. AGVs are becoming an integral part of automated manufacturing systems. They are with programming capabilities for destination, path location, and positioning. The AGVS belong to a class of highly flexible, intel1igent versatile material-handling systems used for materials loading and unloading throughout the facility.

Automated Guided Vehicle (AGV) is the advanced material handling applications. AGV play an important part in automating the manufacturing unit because they not only connect all faces of the factory by the horizontal movement of materials, but allow management to control and direct manufacturing processes.

The AGV can be defined as a vehicle equipped with automatic guidance equipment, either electromagnetic or optical. Such a vehicle is capable of following prescribed guidepaths and may be equipped for vehicle programming and stop selection, blocking, and any other special functions required by the system.

One of the interesting feature of AGVs is the collision avoidance capability. That is, the vehicle comes to a dead stop before any damage is done to personnel, materials, or structures.

2.4.4.1 The Components of AGV

There are four main components of an automated guided vehicle system:

1. The vehicle*:* It is used to move the material within the system without a human operator.
2. The guide path*:* It guides the vehicle to move along the path.
3. The control unit*:* It monitors and directs system operations including feedback on moves, inventory, and vehicle status.
4. The computer interface*:* It interfaces with other computers and systems such as the mainframe host computer, the automated storage and retrieval system (AS/RS), and the flexible manufacturing system (FMS).

AGV's Control Systems

There are three types of AGVS control systems. They are 1-1

• **Computer-controlled system*:***

In this system, all the transactions and AGVS vehicle movements are controlled and monitored by the system controller. The guide path controller controls the guide path of the AGVS and transfers the information to the AGVS process controller. The AGVS process controller directs the movement of the AGVS vehicles.

NOTES

• **Remote dispatch control system**:

In this system a human operator is required to issue instructions to the vehicle through a remote control station. The control system sends destination instructions directly to the vehicle. Therefore, the human operator does not have any direct control over the AGVS vehicle.

• **Manual control system**:

In the manually controlled system, the operator gives commands to AGVS. The operator gives instructions like loading the vehicle, entering a destination and unloading. A manually controlled system is simple and the least expensive of all control systems. The efficiency of the system depends on the skill and performance of the operator.

2.4.4.2 Applications of AGVS

AGVS have numerous applications and have already been applied by many manufacturing plants and companies. New applications are being developed as technology improves and as experience is gained. Some of the most common applications of the AGVS are:

- Raw material storage
- Finished goods storage
- Assembly operations
- Flexible manufacturing systems
- Manufacturing operations

Technical and Economic Benefits of AGVs

- *Economic Justification*: AGV systems are proving to be the most economical method of moving material.
- *Interface with Other Systems*: AGV systems are designed to interface with other material-handling systems including conveyors, automatic storage/retrieval systems, production lines, and other devices.
- *System Accountability*: Computer control means planned delivery, transaction audit records, on-line interface to production and inventory control systems and management information on the vehicle and workstation production.
- *Reduced Labor/increased Productivity*: In cases where driverless vehicles are used, substantial savings are realized due to labor reduction.
- *Guide path Easily Expanded:* As material movement needs change or plant size increases, AGV systems can be expanded or modified quickly and at low cost.

NOTES

- *Expandable System Capacity*: As material movement needs an increase, load movement capacity in the AGV system is easily accomplished by adding one or more vehicles.
- *Unobstructed Aisles*: Control wires for AGV systems are installed in the floor and therefore, leave no '*above-floor obstructions*'.
- *Destinations Unlimited*: AGV systems can be designed with an unlimited number of pick-up and delivery points.
- *Less Equipment Damage*: There is less product and equipment damage when AGV systems are used to move material because the vehicles travel on a predetermined route.
- *Reliable System Control*: All automatic guided vehicles are equipped to allow manual override for the special material or vehicle movement situations.
- *Energy Conservation*: AGV systems require very little energy to operate.
- *Ease of Installation*: AGV systems can be installed in less time than most other material handling systems.
- *Installation in Existing Buildings*: AGV systems can be installed in existing buildings with minimum interference to ongoing operations.

Review Questions:

1. Name any two Conveyors.
2. List any two component of Robotics.
3. Name any two trucks.
4. Name any two cranes.
5. State any two advantages of Robots in Industry.
6. Name any two components of Robots.
7. List three benefits of AS/RS.
8. Expand AGV.

2.5 JUST IN TIME

Just In Time (**JIT**) is a philosophy, wherever an organization adopts this philosophy to strive for excellence in their activities. **JIT** is considered to be a production strategy which enables to identify the non value added activities and eliminate those activities. The activities include the activities starting from the design to delivery of the product. **JIT** helps in achieving the listed objectives like.

- *Zero defects*
- *Zero lead time*
- *Zero Breakdowns*
- *Zero Handling*
- *Zero Set uptime*
- *Zero lot excesses*
- *Zero Surging*

NOTES

2.5.1 Problems of Conventional Production Systems:

The well known Conventional Production Systems like Continuous Production System and the Intermittent Production System have their own limitations as you have read in the previous sections. The continuous production system has the shortcomings like for eg; this kind of system is not suitable for variety production. If there is a change in the product design, this system needs to be changed as it lacks in flexibility. The work forces are specialized work forces. But the workstations are properly balanced, comparatively you need less work in progress inventory. The manufacturing cycle time is comparatively low. In the case of intermittent production system, the system is more of process based. Since, it does the variety of products. The product has to wait for long time in the queue for the processing. This results in more in process inventory. But this system has the advantage of producing more no of variety production. Flexibility is in built in this system.

Since the traditional system have these kinds of problems, so we need a system incorporating flexibility, balanced work station with multi skilled work force, with less waiting time of the products.

JIT provides solution for the problems of conventional production system.

2.5.2 Conventional Vs. JIT Attitudes

Table2.1 - Conventional Vs. JIT Attitudes

Conventional Attitudes	JIT Attitudes
Some defects are acceptable	Zero defects are necessary and attainable
Large lots are efficient (more better)	Ideal lot size is one (less is better)
Fast production is efficient	Balanced production is efficient
Inventory provides safety	Safety stock is a waste
Inventory smoothes production	Inventory is undesirable
Inventory is an asset	Inventory is a liability
Queues are necessary	Queue should be eliminated
Suppliers are adversaries	Suppliers are partners.
Supply sources lead to safety	Sources of supply lead to control
Breakdown maintenance is enough	Preventive maintenance is essential
Long lead time is better	Short lead time is better
Setup time is given	Setup time should be zero
Management is by edict	Management is by consensus
Work force is specialized	Work force is multifunctional

NOTES

The above table illustrates the difference between Conventional System and JIT system. JIT is also considered as Inventory System in addition to considering it as production strategy. The reason for considering JIT as an Inventory System is that the main emphases of the JIT is the product, should flow in the production system without any impediments.

But Inventory hides much type of impediments like:-

- Bad raw materials-
- Machine break downs-
- Poor quality-
- Worn tools-
- Delayed deliveries
- Unavailable material handling equipment
- Unavailable inspectors or setup persons

If you have Inventory, the above problem will not come to the lime light very much. So JIT focus on mainly on inventory reduction to pave the way for the smooth flow of product in the system.

2.5.3 JIT as a waste elimination tool

As it is mentioned, JIT emphasis on the inventory reduction. You can see in this section what re-engineering by the JIT requires in the input, processing and output sides of an operation system.

Figure 2.3 - JIT as a waste elimination tool

- Customer order	- Group Technology	- Customer order
- Accurate Forecasting	- Uniform plant loading	- Accurate forecasting
- Reliable supplier	- Kanban type production	
	- Control system	
	- Quality Control	

Raw Material inventory reduction:

The following situations lead the organization to invest less in Raw Material inventory.

- The exact proportion of the input requirement is known, provided the organization produces the product based on customer order.
- Accurate finished good forecasting enables the organization to stock less.
- Fewer but better suppliers.
- Partnership with the supplier.

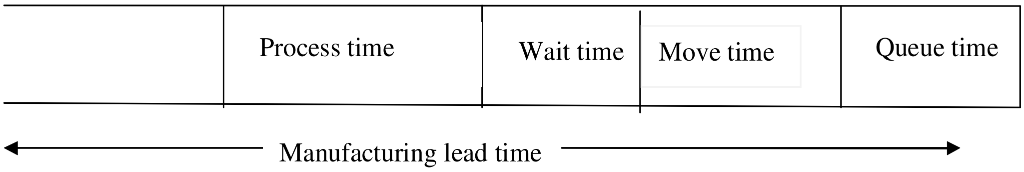
NOTES

- More local suppliers to reduce lead time.
- Frequent delivery of parts directly to the point of use.
- Quality at the source by preventing defects and doing it right the first time.

Work in Progress reduction:

Work in Progress is the result of long manufacturing lead time, improper balance of the workstations. First let us analyze the constituents of manufacturing lead time. Manufacturing lead time consists of

Figure 2.4 - Work in Progress reduction



Except process time, all other times are non value added times. The organization should re-engineer first to reduce non value added times.

Setup time:

It is the time to setting up the machine. It involves the time included

- in bringing the raw material and tools to the work place.
- in cleaning and lubricating the machines.
- in changing the die and jigs & fixture etc.

The relationship between setup time, setup cost and production is given below:

Setup time is **Proportional** to Setup cost.

Production quantity = **f** (Setup cost)

So, reduction the set up time in enables the reduction in set up cost. This in turn reduces the economic production quantity to be produced. So JIT advocates one unit, is the economic production quantity. The setup time reduction is Possible through adopting the following means:

- **Method analysis**
- **Quick disconnects**
- **Tinged bolts**
- **Clamps**
- **Roller platforms**
- **Tool carouses**

NOTES

Process time:

It is the actual operation time on a product. This usually contributes less than 10% of the total manufacturing time.

Wait time:

This is the waiting time of the product to be moved for the next operation. This time is reduced provided the movement of material and the completion of operation are synchronized. This time is reduced through proper material handling planning.

Move time:

This is the movement time from one work station to another work station. This time is lessened if the work stations are adjacent.

Queue time:

This represents major portion of the manufacturing cycle time. This is the idle time of the product, waiting for the operations because the machine center from which the processing sought for, engaged by another product. This time depends upon the routing procedure adopted, priority rule assigned for the product.

If you reduce the non value added times by the way and means mentioned above, the investment on, namely, the material, labor and manufacturing overhead in work in progress, inventory gets reduced. This is possible by adopting the group technology principle, Kanban production control, assuming machine reliability through preventive maintenance.

Finished Good Inventory Reduction:

Finished good inventory is reduced if you reduce the uncertainty related with the timing and the quantity of the customer requirement. The means for the uncertainty reduction:

- Production based on the customer orders.
- Accurate forecasting or free from errors .
- Through better customer relationship, retaining the customer helps in executing agreement.
- To fulfill the customers future requirement.
- Retaining the customer through better customer relationship enables the organization in executing agreement to fulfill his future requirement.

Group Technology:

This is already explained in the previous unit's section (1.7.4 Group Technology)

2.5.4 KANBAN Production control system:

KANBAN is a Japanese word, meaning, CARD. There are two types of KANBAN one is called CONVENANCE KANBAN and the other one is PRODUCTION KANBAN CONVENANCE KANBAN acts as a move order authorizing the movement of material from one center to another work center. PRODUCTION KANBAN acts as a work order authorizing the work center to start production. You can understand the working of KANBAN Production control systems by considering intermediary work centers n-1, n and n+1 in a manufacturing.

2.5.4.1 Working of KANBAN

1. The production centers know in advance the production schedule.
2. The operator in the production center 'n+1' goes with conveyance KANBAN to the production center 'n'. Where a container have the parts required for the production center 'n+1'. Then he removes the production KANBAN and keeps it in the rack of the production center 'n'.
3. Then he keeps the conveyance KANBAN in the container and move with the container to his work station n+1.
4. The order in which the production KANBAN in the rack gives indication to the operator in the work center 'n' about the priority based on which the product have to be processed in the centre 'n'.
5. In the production center 'n' based on the production schedule, when the time for starting his operation reaches.

   - He goes with conveyance KANBAN to the production center 'n-1'.
   - Remove the production KANBAN in the container and keep it in the rack of center n-1 and keep the conveyance KANBAN in the container and move with the container to the workstation 'n' to start further processing on the product.

The whole sequences of activities are portrayed in the figure2.5.

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Figure2.5 - Working of KANBAN

From the above sequence you can understand that the JIT operates in the **pull system** basis. That is the down stream pulls the components from the upper stream for the production. But, in the case of traditional production system, it operates, based on

NOTES

the **push system**. In this case, whether the down stream requires the component at the time or not, the upper stream simply pushes the component to down stream as and when it completes the component that results in comparatively more work in progress inventory.

2.5.5 Uniform Loading:

You can understand the concept of uniform loading through an example, suppose a product 'x' of 2000 quantity is required in a month. Assume that the organization works for 20 days in a month, then 2000/20 = 100 units, the organization has to produce in a day. Uniform loading means, the organization never produces the product excess of 100 units in a day even though there is an idle capacity available in a day. This means that JIT insists not on the efficiency (Utilization of resources) because if the product is produced faster than the required, then it adds more costs to the organization through the following:

- Containers are needed to hold them.
- Trucks are needed to move them.
- Warehouse space is needed to store them.
- Money is needed to finance the inventory.
- Accountants are needed to keep track of it.
- Schedulers are needed to indicate when to produce more.

Quality Control:

In JIT, as par as in process inspection concerned, the worker act as a inspector and he is responsible for the quality. As it is mentioned, the work force is a multi 1-1 skilled workforce. The worker is trained in the inspection process also, if there is any problem regarding the quality, the whole production stops. After, the quality problem is rectified, the production starts. In JIT, the quality improvement is done through **Total Employee Involvement (TEI),** quality circles. The emphasis is more on the quality but not on the quantity. Workers are responsible for feeding only good quality parts to the downstream operations. The machines are kept in good working conditions so that it produces good quality part. The worker acts as a maintenance man to get defect free product. JIT operates on the policy of prevention better than cure.

Review Questions:

1. What does JIT aim for?
2. How do you achieve flexibility and less work in progress inventory?

NOTES

3. What is meant by wait time?
4. What is meant by queue time?
5. What does KANBAN stand for?

2.6 ABC ANALYSIS (ALWAYS BETTER CONTROL)

Any organization usually deals with lots of items. It is very difficult to exercise control over all the items. Controlling means transactions related to inventory, degree of control, type of records to be maintained, lot sizes, frequency of review, size of safety stock to be maintained etc.

ABC analysis helps to classify the thousands or even millions of individual items into three groups namely items belonging to A group, B group, C group items respectively. ABC analysis is done based on the Pareto's principle. Consumption value is the basis for ABC classification. Consumption value is the product of unit price and consumption.

Mechanism of doing ABC classification:

Steps involved:

1. Collect previous year consumption and unit price for each item.
2. Multiply the consumption and unit price for each item to get the consumption value.
3. Rank the items corresponding to the consumption value.
4. Calculate cumulative consumption value against each item.
5. Find the percentage of cumulative consumption value.

Usually to classify the items into 'A' class there is leverage available. The leverage is 60 to 70 percentage of the consumption value. This means the cut-off value can be fixed in between 60 to 70 percentage of consumption and the corresponding items which contribute up to the cut-off value are classified as a class items.

Similarly, to classify the items into B class, there is a leverage of the consumption value to the extent of 10 to 20 percentage of the consumption value.

To classify the items into C class, there is a leverage of the consumption value to the extent of 10 to 20 percentage of the consumption value.

Table 2.1

Class of items	**Cut-off % of Consumption Value**
A	60-75
B	10-20
C	5-10

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Illustrated Example: 2.1

1. Bulchand & Co. company inventories 20 items. The company decides to setup an ABC inventory system with 10 % of A items, 20% of B items and 70% of C items. The company records provides the information, which is as follows:

Table 2.2

Item Code	Annual usage in units	Cost per unit (Rs)
G	2,500	150
H	15,000	90
I	12,000	100
J	8,000	50
K	1,00,000	50
L	25,000	300
M	80,000	500
N	2,000	300
O	3,000	70
P	6,500	60
Q	10,000	75
R	6,000	20
S	20,000	50
T	40,000	90
U	1,20,000	350
V	20,000	200
W	1,500	350
X	4,000	100
Y	4,500	200
Z	7,000	40

Analyze the above items into ABC categories on the basis of the information and prepare a report showing your findings with comments.

NOTES

Solution
Table 2.3

Item code	Annual usage in units	Cost per unit (Rs.)	Consumption Value	Ranking
G	2,500	150	3,75,000	17
H	15,000	90	13,50,000	7
I	12,000	100	12,00,000	8
J	8,000	50	4,00,000	14
K	1,00,000	50	50,00,000	4
L	25,000	300	75,00,000	3
M	80,000	500	400,00,000	2
N	2,000	300	6,00,000	12
O	3,000	70	2,10,000	19
P	6,500	60	3,90,000	16
Q	10,000	75	7,50,000	11
R	6,000	20	1,20,000	20
S	20,000	50	10,00,000	9
T	40,000	90	36,00,000	6
U	1,20,000	350	420,00,000	1
V	20,000	200	40,00,000	5
W	1,500	350	5,25,000	13
X	4,000	100	4,00,000	15
Y	4,500	200	9,00,000	10
Z	7,000	40	2,80,000	18

Table2.4

Ordered Ranking	Item Code	Consumption Value value	Cumulative consumption consumption	Percentage of Cumulative value	Class
1	U	420,00,000	420,00,000	37.90	A
2	M	400,00,000	820,00,000	74.14	
3	L	75,00,000	895,00,000	80.92	B
4	K	50,00,000	945,00,000	85.44	

5	V	40,00,000	985,00,000	89.05	
6	T	36,00,000	1021,00,000	92.31	
7	H	13,50,000	1034,50,000	93.53	C
8	I	12,00,000	1046,50,000	94.62	
9	S	10,00,000	1056,50,000	95.52	
10	Y	9,00,000	1065,50,000	96.33	
11	Q	7,50,000	1073,00,000	97.01	
12	N	6,00,000	1079,00,000	97.55	
13	W	5,25,000	1084,25,000	98.03	
14	J	4,00,000	1088,25,000	98.39	
15	X	4,00,000	1092,25,000	98.75	
16	P	3,90,000	1096,15,000	99.10	
17	G	3,75.000	1099,90,000	99.44	
18	Z	2,80,000	1102,70,000	99.70	
19	O	2,10,000	1104,80,000	99.89	
20	R	1,20,000	1106,00,000	100	

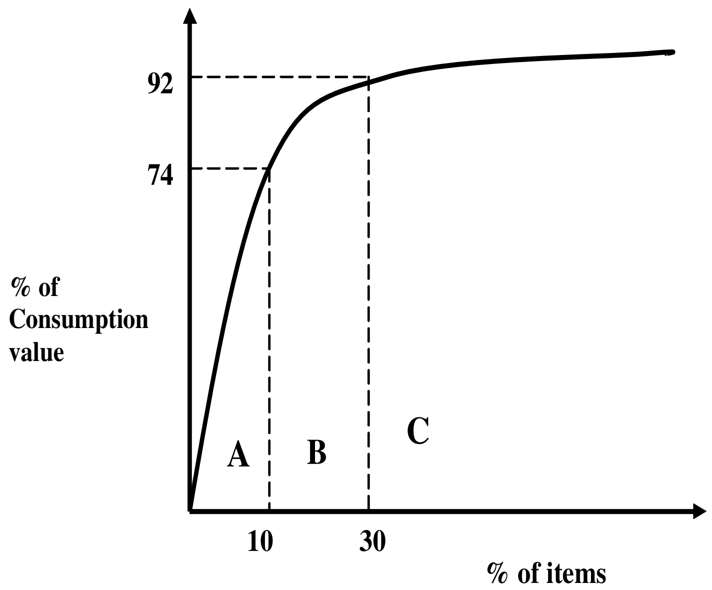
NOTES

Table2.5

Class	No. of items	% of items	Consumption Value in Lac Rs.	Cut-off % of Consumption value
A	6	30	450	73.48
B	7	35	120	19.59
C	7	35	42.25	6.9

NOTES

Figure 2.6 - Graphical representation of ABC analysis



2.6.1 Kinds of Control

Purpose of classifying the items into ABC is to control over each item. The degree of control required for A class is not same for B and C class items. The following table helps the material manager in the kind of control to be exercised on these items.

Advantages of ABC Analysis:

1. Better exercise of control over all materials.

2. The capital invested in inventory can be reduced to minimum levels.

3. Warehouse and storage costs can be reduced.

Limitations of ABC Analysis:

- ABC analysis mainly provides a guideline for inventory management. It needs to be supplemented by basic understanding and judgment as there are certain items which may fall into category C or category B due to their low usage value but are otherwise very critical for the production process of the firm. Their inventory levels have to be carefully monitored.
- The ABC analysis, to be effective, needs to be constantly undertaken and periodically reviewed by the management, as the number of items and value of items keep on undergoing changes.
- The practical problem in the usage of ABC analysis is that generally, thousands of items fall in category *C,* as a result, a lot of time is spent on managing inventory of items of this category (even if it needs simple control). The time left for controlling the inventory stocks of categories *A* is therefore much shorter than that required for their effective management.

NOTES

Review Questions:

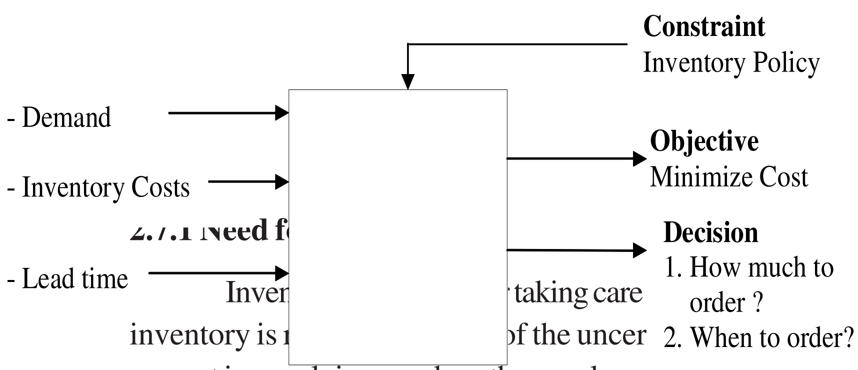
What is consumption value?

2.7 INVENTORY MODELS

Inventory:

Organizations spend lot of money in materials. Material cost represent 20 to 60 percent of the cost of production, even a small saving in material will reflect in profit. Idle scarce material resource is called inventory. Since we invest lot of money in materials and if materials are idle for long time, it is not good for the health of the organization. So it is a must to exercise a control over **Idle Scarce Resources,** otherwise, lot of money is tied in inventory. So had you not invested this money on material, it would have fetched return from the other source. Therefore, an opportunity of earning the return is lost by investing in the inventory, you can see now how can you control the inventory.

Figure 2.7 – Inventory System



2.7.1 Need f

Inven[illegible] taking care [illegible] iness, Ex: raw material inventory is [illegible] of the uncer[illegible] . .supplier may not be prompt in supplying goods or the supply m[illegible] expected. Therefore, to take care of these, you need raw material inventory.

2.7.2 Types of inventory

1. Raw material inventory.
2. Work in process inventory.
3. Finished goods inventory.
4. Supplies.
5. Pipeline inventory.
6. Buffer stock or Safety stock.
7. Decoupling inventory.

NOTES

1,2,3,4 are the basic types of Inventory whereas others are named based on their usage.

Supplies:

Materials which are used other than those used for production of finished goods.

Ex: lubricants, pencil, pen, paper, spare parts.

Pipeline inventory:

It can be raw material, work in progress or finished goods inventory. Ex: Assume supplier is far away. Consumption per day is 20 units, 5 days for transportation

20X5= 100 units are required for the period of transportation.
So if you keep 100 units in your stock it becomes your pipeline inventory.

Decoupling inventory

Inventory **"decouples"** in different stages. It might be raw material, WIP, finished goods inventory. Ex: customer has inventory for 10 days for the consumption. For 10 days the customer is decoupled from the producer.

So, decoupling inventory is the one which decouples the customer and the producer.

Safety stock:

This stock may be raw material, WIP or finished goods which are extra stock required to take care of fluctuation or uncertainties in the demand or lead time.

Usually in a business organization two things are uncertain namely,

- Demand
- Lead time

Inventory models adopted by organizations depend upon the level of uncertainty with the lead time or demand. The following table portrays the type of inventory model of organizations has to be adopted against the lead time and demand situations.

Table 2.6 – Demand and lead time in different types of model to be adopted

Situations	Demand	Lead time	Type of Model to be adopted
1	Constant	Constant	Deterministic Model
2	Constant	Variable	Probabilistic Model
3	Variable	Constant	Probabilistic Model
4	Variable	Variable	Probabilistic Model

NOTES

Lead time:

There are two types of leadtime

- Supply lead time
- Manufacturing lead time

Supply lead time:

This time refers to the time lapse between placing of order with the supplier and receiving it by the customer.

Manufacturing Lead time:

The average time consumed by the product in the plant.

Supply lead time (l)

L=T1+T2+T3+T4+T5
T1= order genesis time and transit time (selection of supplier).
T2= manufacturing time of the product by suppliers.
T2= 0 If the product is readily available with the supplier.
T3= inspection time.
T4= transit time.
T5=receiving time.
If L is high, more inventory is needed to take care of high lead time.

2.7.3 Inventory cost:

Types of inventory cost are

-Ordering cost / setup cost.
-Carrying cost.
- Shortage cost / Back ordering cost.
- Purchase cost.

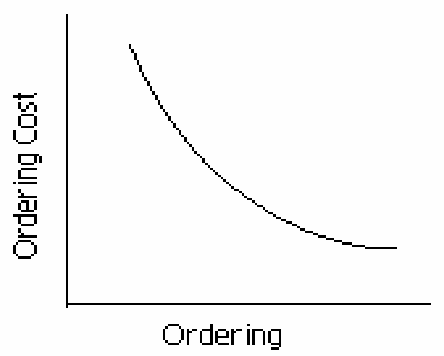
Inventory cost varies according to decisions namely.

Ordering quantity

Ordering cost: (Co)

It is measured per order.
Fig: Ordering Cost behavior against the Ordinary Quantity.

Figure 2.8 – Ordering Cost Curve



Component of Ordering Cost

- Tender and Bidding Cost
- Purchase negotiations
- Selection of vendor
- Preparation and sending of order etc.

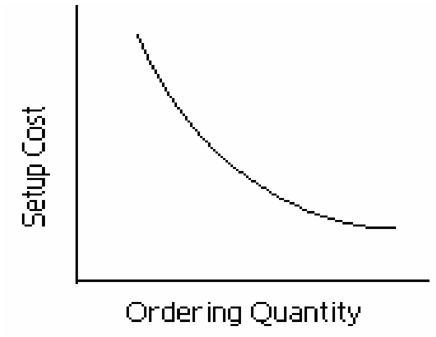
NOTES

Suppose we produce internally without ordering, then there is no ordering cost . It becomes Setup cost.

Setup cost: (Co)

It is measured per setup.

Figure 2.9 – Setup cost Curve



Component of setup cost are

- Cost of cleaning and adjusting production equipment
- Inspection
- Bringing required raw materials.
- Changing dies etc.

As we have seen in both cases, it varies with decision making i.e. how much to order?

Carrying cost: (Cc)

It is the penalty cost which organization incurs because of carrying inventory. Components of carrying cost:

- Capital Cost
- Storage Cost
- Insurance
- Obsolescence
- Deterioration
- Tax etc

Cc = cost of holding one unit per unit time* avg. amount of inventory held per unit time. Carrying cost is measured in terms of percentage.

Example 2.2

Assume that the average inventory in a year for an item = 2000 units
Price of the item = Rs. 100
Average Investment on Inventory = 2000X100
= Rs. 2, 00,000

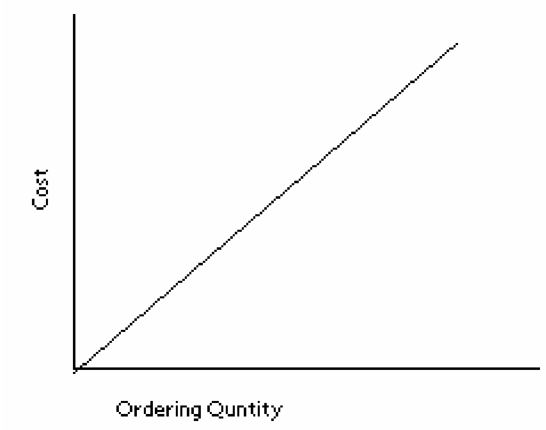
NOTES

By having the average inventory, the organization involves the following additional Cost.

Capital Cost (Opportunity Cost) = 500
Storage = 1000
Insurance = 5000
Obsolescence = 1000
Deterioration = 4000
Tax = 4000
Total = 20,000

Rs. 20,000 contributes 10 percent of the Average investment of Rs, 2,00,000. So the inventory carrying cost for this organization is valued at 10 percent (10 percent of Rs. 100) per unit per year.

Figure 2.10 – Carrying Cost Behavior



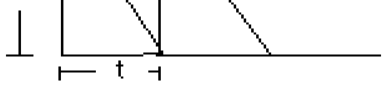
Carrying Cost Behavior against the ordering cost

Shortage Cost (C_s)

Shortage cost is the result of the customers demand not met from the existing stock. Shortage costs are of two types, the one is lost sale and another is the back ordered. In the case of the lost sale the customers demand is not mate. But in the case of the back ordering the customers demand is met at delayed date.

The components of shortage cost are the –

1. cost involved in taking steps to expedite the procurement of the purchased material.
2. cost involved in rearranging the shop schedule to permit the earlier completion of order under consideration.
3. cost involved in working overtime and so on.
4. loss of customers goodwill because of not meeting the customer requirement (future profit loss).
5. present profit loss etc.



NOTES

Some of the components of the shortage cost is difficult to quantify but roughly it is possible to estimate the shortage cost.

Shortage cost = [shortage cost per unit time] * [average shortage per unit time]
= Cs .Is

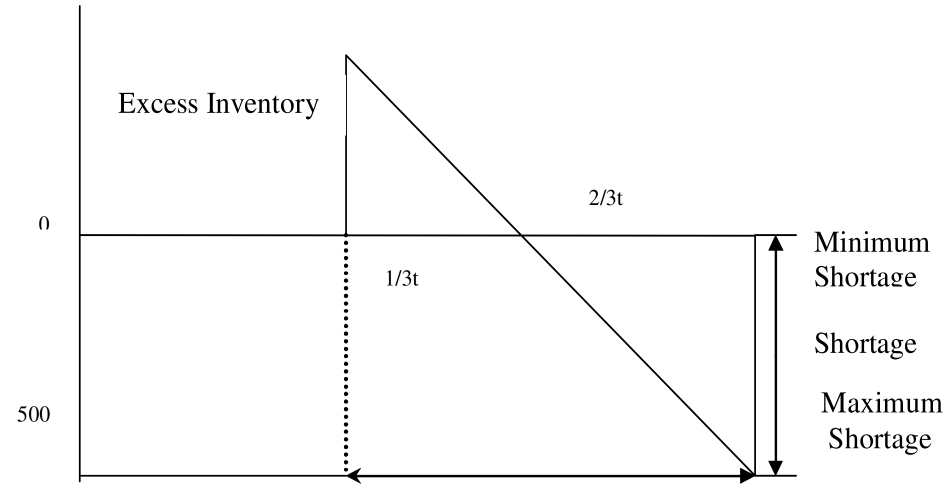
Cs = shortage cost per unit time

Is = average shortage per unit time

Example2.3

Assume that the average shortage cost is calculated per ordering cycle

Figure 2.11 – Inventory level fluctuations for determining average shortage



Suppose t is the ordering cycle.

Assume that in that ordering cycle 2/3t time the i demand is not met from the stock.

The average shortage in the cycle =

[(minimum shortage during cycle + maximum shortage during cycle)/2]X [Proportion of time shortage occurs during cycle]

= (0+500)/2X (2/3t)/t

=500/3

Assume that shortage cost per unit time = Rs. 9

Shortage cost = 9X500/3

=1500

Purchase Cost (Cp)

Purchase cost is the cost of purchase/price of product to be produced. Cp becomes the production cost if it is produced inside the organization.

NOTES

Decision

The decision regarding inventory will be mostly of how much to order?, and when to order? How much to order is related with ordering the quantity but when to order is related with the frequency of ordering and reorder level.

Relevant Cost

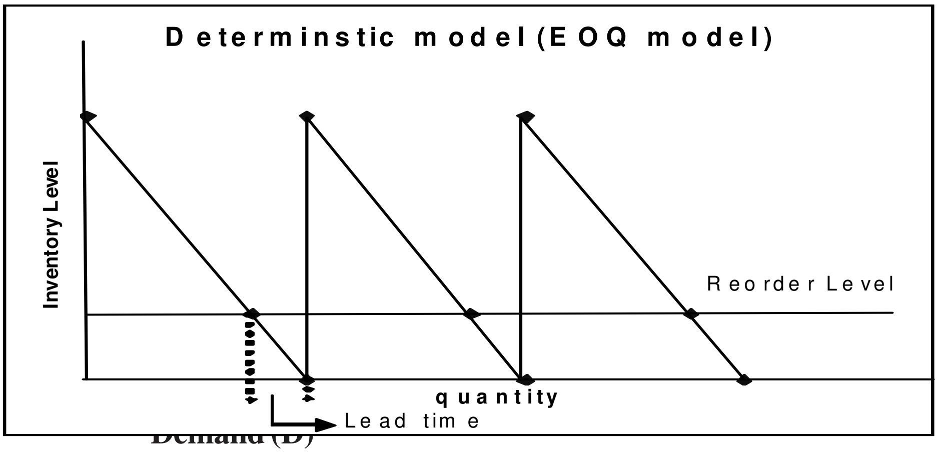
The relevant costs, namely, ordering cost, carrying cost, shortage costs are relevant cost. A cost is said to be relevant cost, provided the cost varies with the decision. If the ordering quantity (Q) is more that results in less shortage cost and ordering cost but the inventory carrying cost will be high. The purchase price is considered to be relevant only when the supplier offers discount.

The purchase cost becomes relevant because the decision, namely, the ordering quantity varies according to the offers provided by the supplier.

1.7.4 Deterministic Model

2.7.4.1 Figure below portrays EOQ model the deterministic inventory model. This is shown time vs. inventory Level.

Figure 2.12 - Deterministic Model



Demand (D)

Demand rate is uniform and is known. D is the annual demand.

Lead time (L)

Lead time is known and constant.

Costs

Ordering cost, carrying cost are known. Purchase cost is irrelevant it means no price discount is offered. Shortage cost is not permitted.

Decision to be taken:

How much to order? - Ordering quantity (Q)

When to order? - Reorder Level

To answer for the questions related with the decisions, you have to proceed as follows:

- Any organization, it has to minimize the total inventory cost.
- Total annual inventory cost = ordering cost +carrying cost+ purchase cost +short age cost
- With regard to this model, the shortage cost is not permitted.
- Total annual inventory cost = ordering cost + carrying cost + purchase cost

Since you should find the ordering quantity and re-order level, next you should consider relevant cost.

(i.e.) total annual relevant cost = ordering cost + carrying cost

= (no. of orders) (ordering cost per order)

+ (average inventory) (Carrying Cost)

D/Q=No. of Orders

Average inventory according to the figure = (min. inventory+ max. inventory)/2

= (0+Q)/2

= Q/2

Total annual relevant inventory cost = (D/Q)×Co+ (Q/2)×Cc

Since you have to establish 'Q'

Differentiating w.r.t. Q and equate it to zero.

= - (D/Q)×Co+ Cc/2=0s

Or

$$\frac{2DCo}{Cc} = Q^2$$

Or Q^2 = 2DCo/Cc

Or Q=?[2DCo/Cc] *Answer to the question how much to order*

NOTES

Total annual relevant inventory cost

= (D/Q)Co+(Q/2)Cc

Substituting q=?[2DCo/Cc]

=(D/?[DCoCc/Cc])Co + (?[DCoCc/Cc]/2)Cc

=

=(?[DCoCc])/?2+?[DCoCc]/?2

=(2/?2) ?[DCcCO]

=?[2DCoCc]

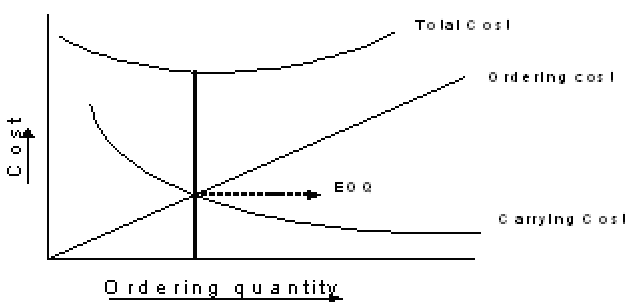
Total annual inventory cost

= Total annual ordering cost + Total annual carrying cost + Total annual purchase cost

$$TC= \frac{D}{Q} C_o + \frac{Q}{2} C_C + D.C$$

= Purchase cost + total annual relevant inventory cost

= DCp+ ?[2DCoCp]



l out EOQ as follows.

mic Order Quantity

Example 2.4

The demand for a certain item is 4800 unit per year. Each unit cost Rs.100. Inventory cost charges are estimated at 15%. No shortage cost is allowed. The ordering cost Rs. 400 per order. Lead time is one day. Assume 250 working days. Find the following:

1. EOQ
2. Time between the orders.

NOTES

3. Number of orders required each year.
4. Minimum relevant Inventory cost.
5. Minimum total inventory cost.
6. Reorder Level.
7. Plot a graph for inventory level fluctuation with time.

Solution

(i) EOQ=v (2DCo/Cc)

=v (2×48000×400)/ (.15×100)

Cc=(15/100) ×100 =1600

(ii) To determine reorder level

= L× (D/12)

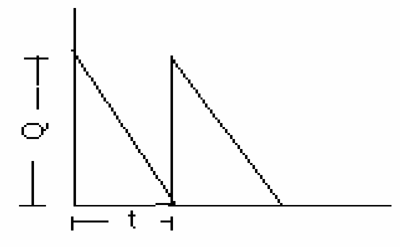
=2×(48000/12250)=192 units

(iii) Time between orders

Q/t =D

t =Q/D

Figure 2.14 – Inventory Level



=1600/48000

=.033 years

=.033 ×250

=8.33 days

(iv) Number of orders

=D/Q

=48000/1600

=30 orders

(v) Total minimum relevant cost

Inventory cost=v2DcoCc

=v2×48000×400× .15× 100

=Rs. 24,000

(vi) Total minimum inventory cost

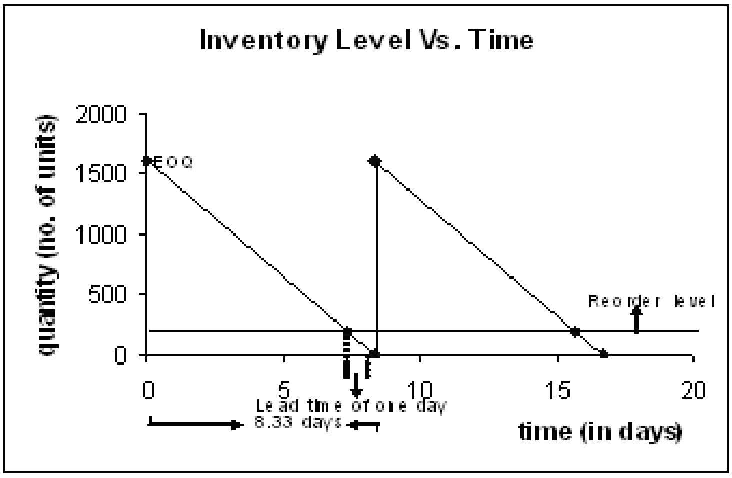
= DCp+v(2CoCc)

=48000×100+24000

=4824000 Rs.

NOTES

Figure 2.15 – Inventory level vs. Time



Above problem is solved scientifically, but this problem can be also be solved graphically.

Table 2.2

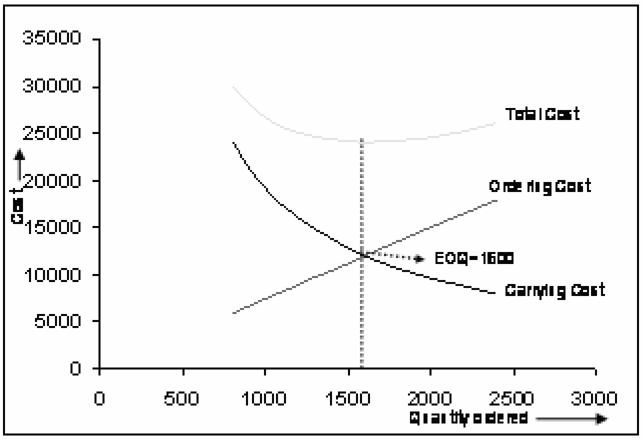
Ordering quantity	No. of orders	Ordering Cost	Average Inventory	Carrying Cost	Total Cost
600	80	32000	300	4500	36500
800	60	24000	400	6000	30000
1000	48	19200	500	7500	26000
1200	40	16000	600	9000	25000
1400	35	14000	700	10500	24500
1600	**30**	**12000**	**800**	**12000**	**24000**
1800	27	10800	900	13500	24300
2000	24	9600	1000	15000	26600

Decreases

Increases

NOTES

Figure 2.16 – Graphical Calculation of EOQ



2.7.4.2 Economic Batch Quantity Model:

1. **Demand:**

-It is known and constant.

-It is nothing but the annual production requirement.

2. Production rate:

-It is known and is estimated based on the capacity of the plant.

3. Lead time:

It is known and constant.

4. Cost:

Setup/ordering cost: Since there is no purchase there is no ordering cost. Only setup cost comes into picture in the place of ordering cost .this is known.

Carrying cost: It is known and constant.

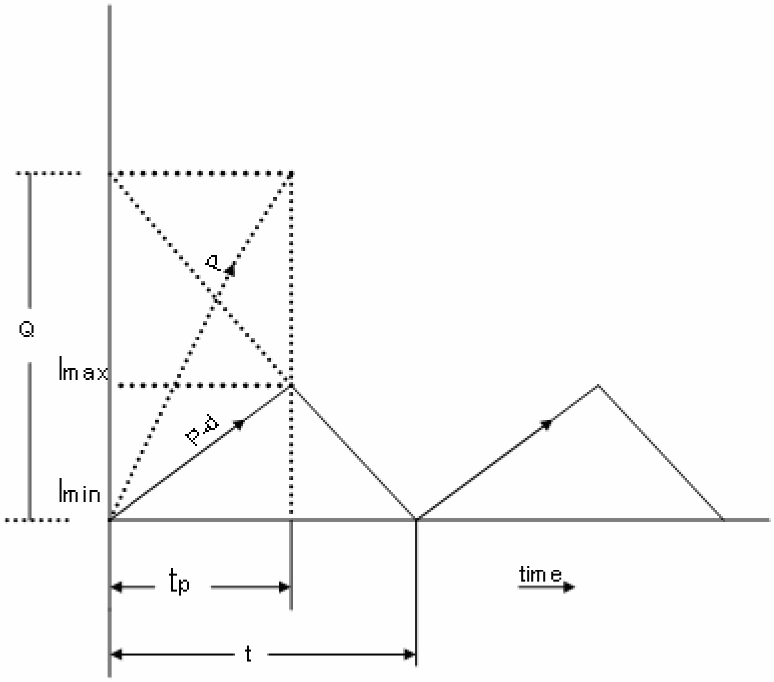
Product cost: assume that product cost per unit does not vary with the production i.e. unit is irrelevant of the quantity of production.

Decision

How much to produce?
When to produce?

The inventory model for this case will be as shown in the figure2.16.

Figure 2.17 – Inventory Model (Economic Batch Quantity)



t_p - It is the production period.
t - It is the time interval between the two productions.

From the fig. it is concluded that up to the period, both production and consumption take place and inventory is built up at the rate of (p-d). Where 'd' is the demand rate.

Once the t_p period is reached there is no production, there is only consumption at the rate of 'd". Next production starts after 't^{th}' period.

To find the quantity of production 'Q', production time period t_p and time interval between production 't'. The following procedure is carried out.
Total inventory cost= setup cost+ carrying cost + production cost + shortage cost.
Total relevant inventory cost= setup cost + carrying cost.
Shortage and production costs are zero because no shortage is allowed and the production cost becomes an irrelevant cost.

From the fig. the average inventory is calculated as follows:

Avg.inventory = (Imax +Imin)/2.
= (Imax+0)/2
= Imax/2.

NOTES

To find Imax , from the fig.

Imax/tp = (p-d).

So, Imax=(p-d)t_p.

To find tp,

t_p×p=Q

t_p=Q/p

Imax = (p-d) Q/p

Imax = (1-d/p) Q.

Total relevant inventory cost =setup cost + carrying cost

Setup cost = (number of setup) × setup cost per setup

= (D/Q) Co

Carrying cost = (Average inventory)× carrying cost per unit

= [(Imax+Imin)/2]×Cc

=(1-d/p)×(Q/2) Cc

Total relevant inventory cost = (D/Q)Co+(1-d/p)(Q/2)Cc

For cost minimization, differentiate w.r.t. Q and equate it to zero.

DC_0/Q^2=(1-d/p)Cc

Q=?[2DCo/Cc(1-d/p)

Total annual relevant inventory cost = D/v [2DCo/ (1-d/p) Cc] +

v [2DCO/ (1-d/p] Cc)/2

=v [DCoCc(1-d/p)/v2 + v[DCoCc(1-d/p)]/v2

= (2/v2) v[DCoCc(1-d/p)]

=v[2DCoCc(1-d/p)]

Total annual inventory cost =v2DCcCo(1-d/p)+CpD

Deducing EOQ from EBQ model

It is known that in case of EOQ model, the production rate is infinity i.e. there is an instantaneous replenishment.

Now

EBQ=v [(2DCo)/(1-d/p)Cc]

So when p = 8

EBQ=EOQ

Example 2. 5

NOTES

ABC Power Company has planned to cover the demand for electricity using coal. Annual demand for the coal input is estimated to be 8lakh tones. It is used uniformly throughout the year. Coal can be strip mined at the rate of 5000 tonnes per day. The setup cost for mining is 200 rupees per run. The inventory holding cost is 5 rupees per tone per day. The total numbers of working days are given as 250. Determine.

1. EBQ.
2. Duration of mining run.
3. Time between runs.
4. Minimum relevant inventory cost.
5. Plot graph showing whole inventory fluctuation Vs time.

Solution:

To find EBQ,

EBQ = v[2DCo/Cc(1-d/p)]

Where

D = 8.00,000 tones per year

D = 8, 00,000/250

= 3200 tones per day

p = 5000 tones/day

Co = Rs2000 /run

Ch = Rs 5 /tones/day

(i) EBQ = v[(2×8,00,000×2500)/(5×(1-3200/5000))]

(ii)Duration of each mining run Q/p = t_p

tp = 42164/5000

= 8.43

= 8.5 days (approx)

(iii) Time between runs

Q = t * d

T = Q/d

= 42164/3200

= 13.17 days.

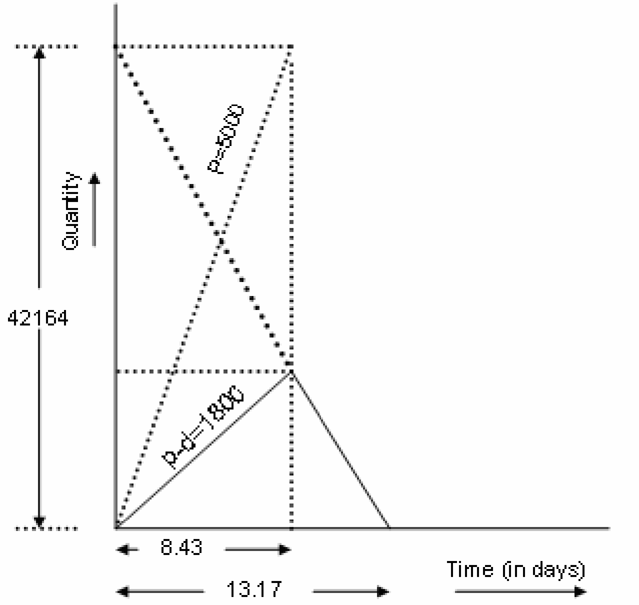
(iv) Minimum relevant inventory cost = v [2DCoCc (1-d/p)

= v [2×8,00,000×2500×5×(1-3200/5000)]

= Rs. 84853

NOTES

Figure 2.18 – Graphical representation of above the example



2.7.4.3 Quantity Discount Model

As it is mentioned already, the purchase cost becomes relevant with respect to the quantity of order only when the supplier offers discounts.

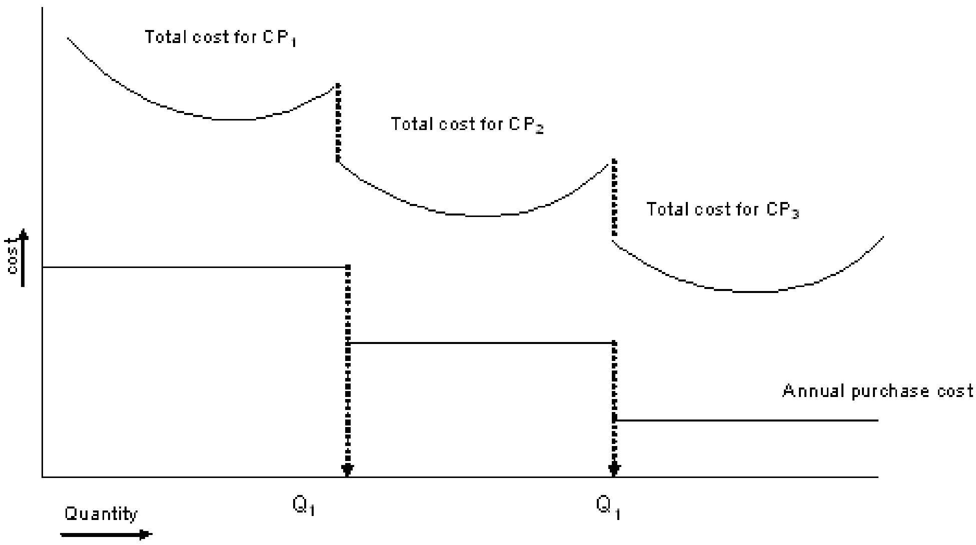
Discounts means if the ordering quantity exceeds particular limit supplier offers the quantity at lesser price per unit.

This is possible because the supplier produces more quantity. He could achieve the economy of scale, the benefit achieved through the economy of scale, he wants to pass it onto the customer. This results in lesser price per unit if the customer orders more quantity.

If you look at in terms of the customer's perspective, the customer should also see that whether it is advisable to avail the discount offered. This is done through a trade off between his carrying inventory by the result of acquiring more quantity and the benefit achieved through purchase price.

NOTES

Figure 2.19 – Quantity Discount Model



Solution:

Start with the lowest price i.e. Rs 9 and to find whether Q is more than or equals to 5000.

EOQ= v(2DCo/ Cc)

= v(2×25000×60)/ 2.7)

= 1054.06 approx. 1055 units

This is not a feasible solution because we expected that Q will be more than or equals to 5000 but the EOQ came as 1055.

By taking the next least value i.e. Rs 11 and to find whether Q is more than 1000 and less than 5000.

EOQ=v (2×25000×60)/ 3.3)

=956 units

This is also not a feasible solution because we expected Q will be more than 1000 and less than 5000 but the EOQ came as 956.

By taking the next least value i.e. Rs 12 and to find whether Q is equals to 1000.

NOTES

EOQ=v (2×25000×60)/ 3.6)

=912.87 approx. is 913units

This is a feasible solution

The total cost of inventory at EOQ is

TC=v (2×D×Cc×Co) + D×P

= v (2×25000×60×3.6) + (25000×12)

= Rs 303286.33

Total inventory cost at other ordering quantities are -

Total inventory cost for Q equals to 5000

TC= (D/Q) ×Co + (Q/2) ×Cc + D×P

= (25000/5000) 60 + (5000/2) 2.7 + (25000*9)

= 232000

Total inventory cost for Q between = 1000 and 5000

TC= (D/Q)*Co + (Q/2)*Cc + D*P

= (25000/1000) 60 + (1000/2) 3.3 + (25000*11)

= 278150.

The possible savings is equal to total inventory cost at feasible EOQ, total inventory cost at 5000 units.

The possible savings are = 303286-232000

= 71,286

A ordinary quantity 5000, the total annual inventory cost is 2, 32,000

2.7.5 Probabilistic Models

In the previous section, it is assumed that the lead time and demand are constant. But in real life situations it is not so. The demand is always uncertain because it is difficult to exactly estimate the required quantity by the customer and the supplier is also usually not reliable. In the sense, he doesn't supply in the specified time period. Considering this kind of situation, the decision should be taken regarding the quantity of ordering, time at which the order to be placed, the time between the orders and how much inventory to be kept against the uncertainty of demand and the lead time become cumbersome.

To deal with the above scenarios, the inventory model to be adopted is known as **Probabilistic Inventory Model**.

NOTES

The inventory models called probabilistic inventory model because the demand or lead time or both are random variables. The probability distribution of demand and lead time should be estimated..

The inventory models answers for questions related to the decision raised above are called **Probabilistic Inventory Model.**

2.7.5.1 One such model is Fixed Order Quantity Model (FOQ).

In this model,

1. The demand (D) is uncertain, you can estimate the demand through any one of the forecasting techniques and the probability of demand distribution is known.
2. Lead time (L) is uncertain, probability of lead time distribution is known.
3. Cost(C) all the costs are known.

   -Carrying costs Cc

   -Ordering costs Co

Stock out Cost

It is difficult to calculate stock out cost because it consists of components difficult to quantify so indirect way of handling stock out cost is through service levels. Service levels means ability of organization to meet the requirements of the customer as on when he demands for the product. It is measured in terms of percentage.

For example: if an organization maintains 90% service level, this means that 10% is "stock out" level. This way the stock out level is addressed.

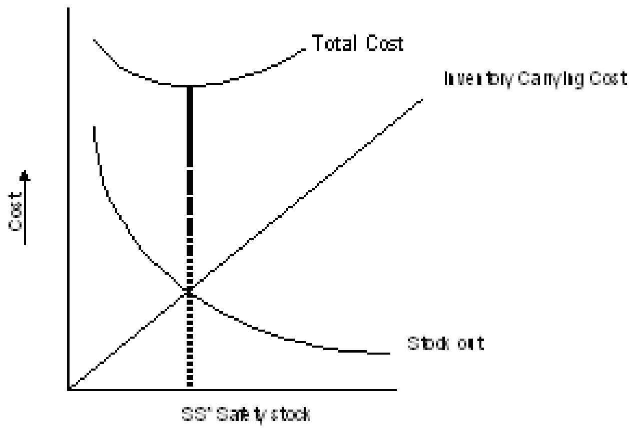
Safety stock

It is the extra stock or buffer stock or minimum stock. This is kept to take care of fluctuations in demand and lead time.

If you maintain more safety stock, this helps in reducing the chances of being "stock out". But at the same time it increases the inventory carrying cost. Suppose the organization maintains less service level that results in more stock out cost but less inventory carrying cost. It requires a tradeoff between inventory carrying cost and stock out cost. This is explained through the following figure2.19

NOTES

Figure 2.20 – Safety Stock



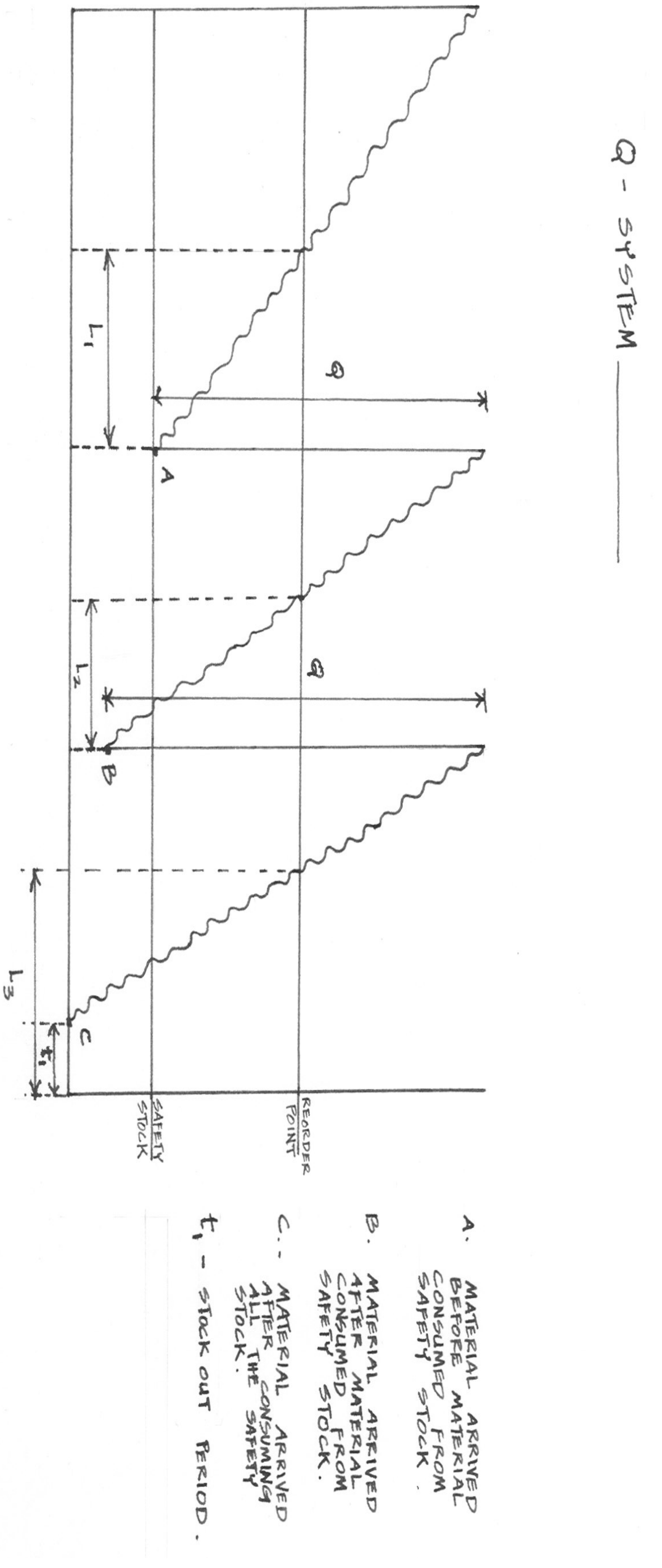
Safety stock (S.S*) is to be stocked by the organization.

Working of fixed order quantity model

Fixed order quantity system is also known as **continuous review system** or perpetual inventory system or Q system. In this system, the ordering quantity is constant. Time interval between the orders is the variable.

The system is said to be defined only when if the ordering quantity and time interval between the orders are specified. EOQ provides answer for ordering quantity. Reorder level provides answers for time between orders. The working and the fixed order quantity model is shown in the figure2.20 (next page).

Figure 2.21 – Fixed Order Quantity Model



NOTES

NOTES

Application of fixed order quantity system

1. It requires continuous monitoring of stock to know when the reorder point is reached.
2. This system could be recommended to" A" class because they are high consumption items. So we need to have fewer inventories. This system helps in keeping less inventory comparing to other inventory systems.

Advantages

1. Since the ordering quantity is EOQ, comparatively it is meaningful. You need to have less safety stock. This model relatively insensitive to the forecast and the parameter changes.
2. Fast moving items get more attention because of more usage.

Weakness

1. We can't club the order for items which are to be procured from one supplier to reduce the ordering cost.
2. There is more chance for high ordering cost and high transaction cost for the items, which follow different reorder level.
3. You can not avail supplier discount. While the reorder level fall in different time periods.

Illustrative Example 2.7

1. ABC company requires components at annual usage rate of 1200 units. The cost of placing an order is Rs 100 and has a five day lead time. Inventory holding cost is estimated as Rs 30 per unit per year. The plant operates 250 days per year. The daily demand is normally distributed with a standard deviation of 1.2 units. It has been decided at to use fixed quantity inventory system based on a 95% service level. Specify the following

   1. Ordering quantity
   2. Re order level

Solution:

Given data
Demand 1200 units
Ordering Cost Rs 100
Carrying cost Rs 30 per unit per year
Lead Time 5 days
Operating days 250 per year.
Standard deviation of demand
per day is 1.2 units.

NOTES

To determine the ordering quantity
EOQ = v(2DCo/ Cc)
= v2×1200×100/30
= 89.4 approx. = 90 units
To determine the reorder level

Reorder level = average demand during lead time +safety stock.

Safety stock calculations:

To find out the safety stock as it is mentioned already that you need to use the service level. As per this problem it is given 95% service level that means 5% stock out level. We need to have safety stock level against this 5% stock level. It is also given in the problem that consumption of items follows normal distribution.

The mean lead time demand distribution is = (1200/250) ×5=24 units = X_L

The mean of the distribution is (1200/250) ×5
= 24 units
Variance of the distribution, since per day standard deviation is given. First it is to be converted into variance by taking the square
(1.2)*(1.2)= 1.44 units
From the per day variance, the five days variance determined as follows because leadtime equal to 5 days.

σ_L

If V is the variance of one day then the five day variance is
V+V+V+V+V=5*V
Standard deviation = ?(5V) = ?5?v=?5ó
For 5 days = ?(5 ó
ó = standard deviation per day

In common, to convert the per unit standard deviation into lead time standard deviation, Based on above calculation it could be deduced that

$ó_{L=vL}$ × ó

Where is the standard deviation of demand during lead time.
? is the standard deviation of demand per unit time
Since the demand during lead time follows the normal distribution.

It is given that 95% service level and 5%stock out level.
For 5% stock out level, the safety level is estimated as follows:
From the distribution you can calculate the safety stock using the formula

K× σ_L

K is the safety factor for 5% stock out level; the K value is calculated using the standard distribution table.

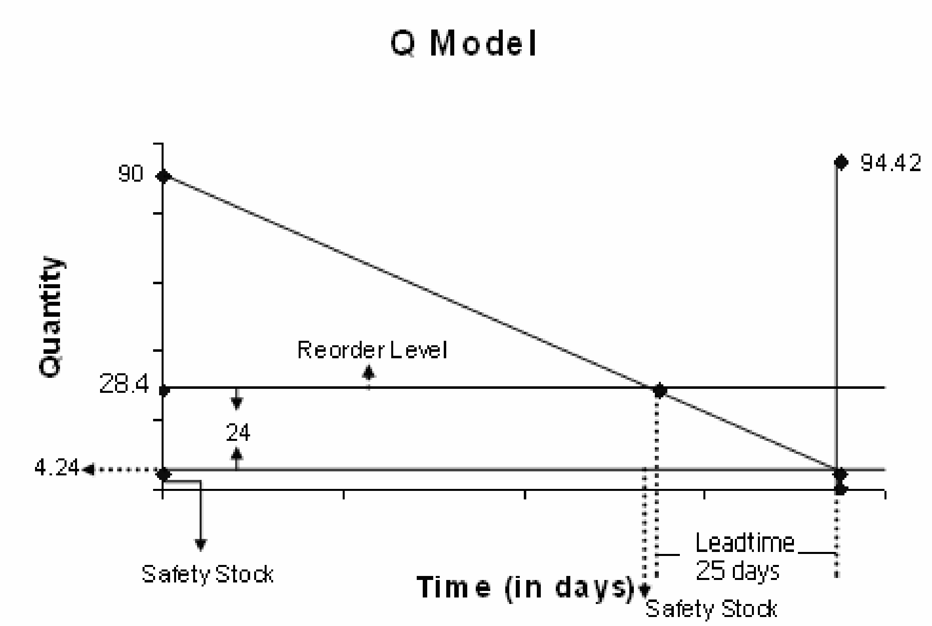
NOTES

To calculate K at 5% stock out level

K=1.65 from the table
Safety stock= K × σ_L

= 1.65*2.68
= 4.42
To find the re order level
= 24+4.42
= 28.42 units

Figure 2.22 – Graphical Presentation of Example 2.7



Review Questions:

1. Define Inventory
2. What is pipe line inventory?
3. Give formulae for EOQ?
4. Give formulae for EBQ
5. When purchase cost become relevant?
6. In which situations one has to adopt probabilistic model?

NOTES

2.8 MATERIAL REQUIREMENT PLANNING

2.8.1 Introduction

Material Requirements Planning (**MRP**) is a computer-based production planning and inventory control system. MRP is concerned with both production scheduling and inventory control. It is a material control system that attempts to keep adequate inventory levels to assure that required materials are available when needed. MRP is applicable in situations of multiple items with complex bills of materials.

The major objectives of an MRP system are to simultaneously:-

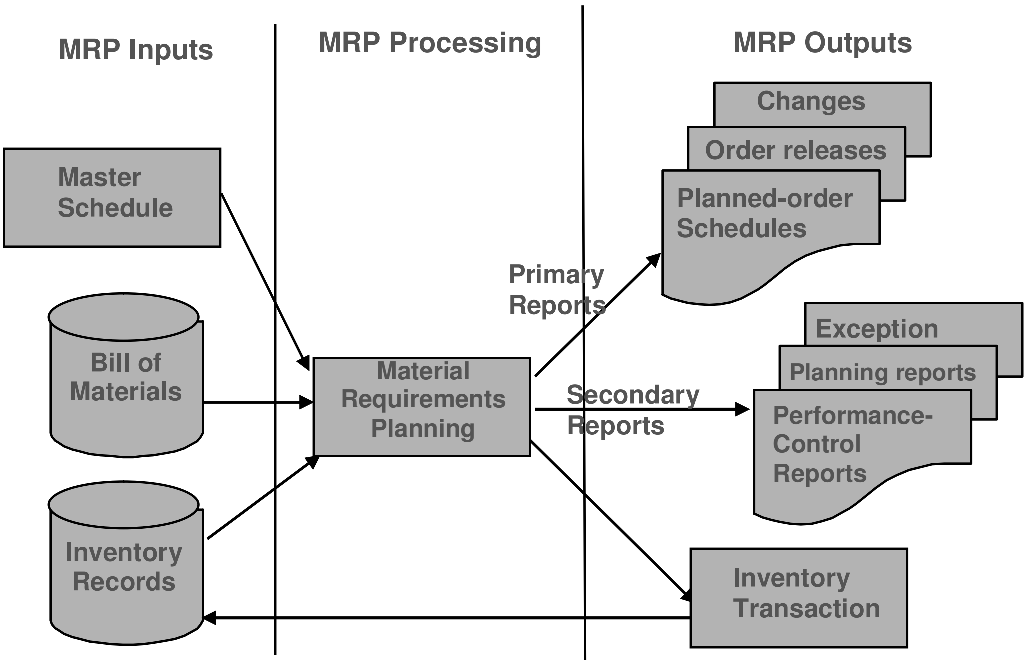
1. ensure the availability of materials, components and products for planned production and for customer delivery,
2. Maintain the lowest possible level of inventory,
3. Plan manufacturing activities, delivery schedules and purchasing activities.

MRP is especially suited to the manufacturing settings where the demand of many of the components and subassemblies depend on the demands of items that face external demands. Demand for end items is independent. In contrast, the demand for components used to manufacture end items depend the on the demands for the end items. This is known as Derived Demand. The distinctions between the independent and derived demands are important in classifying the inventory items and in developing systems to manage items within each demand classification. MRP systems were developed to cope better with derived demand items.

2.8.2 Overview of MRP system

The following figure shows the general overview of an MRP system.

Figure 2.23 – MRP system



NOTES

2.8.3 Inputs to MRP system

There are three major inputs for an MRP system. They are

1. Master production schedule,
2. Bill of Material
3. Inventory status records

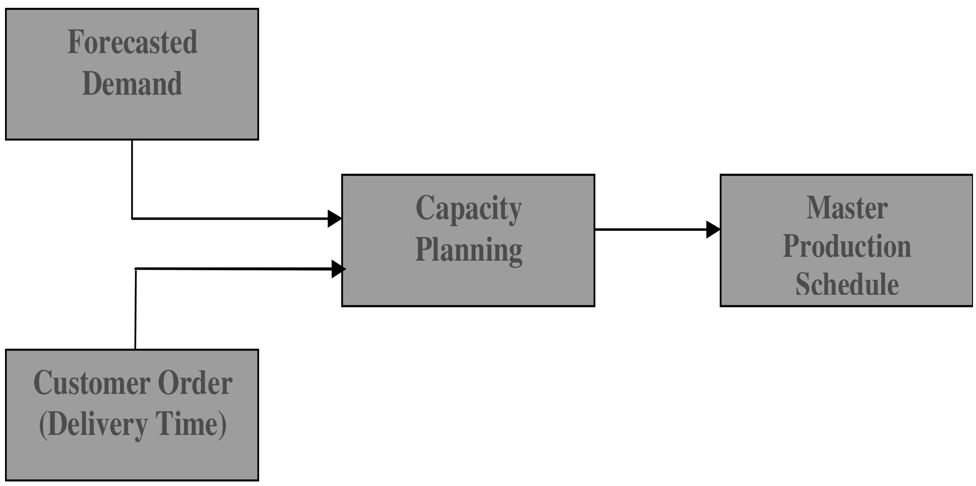
Without these basic inputs the MRP system cannot function.

1. Master production schedule

The demand for end items is scheduled over a number of time periods and recorded on a master production schedule (MPS). The master production schedule expresses how much of each item is wanted and when it is wanted. The MPS is developed from forecasts and firm, the customer orders for end items, safety stock requirements and internal orders. MRP takes the master schedule for end items and translates it into individual time-phased component requirements.

Overview of the Master Production Schedule

Figure 2.24 - Overview of Master Production Schedule



NOTES

Master Production Schedule- Example

Table 2.7

Aggregate Production Plan for Mattresses

Month	1	2
Mattress production	900	950

Master Production Schedule for Mattress Models

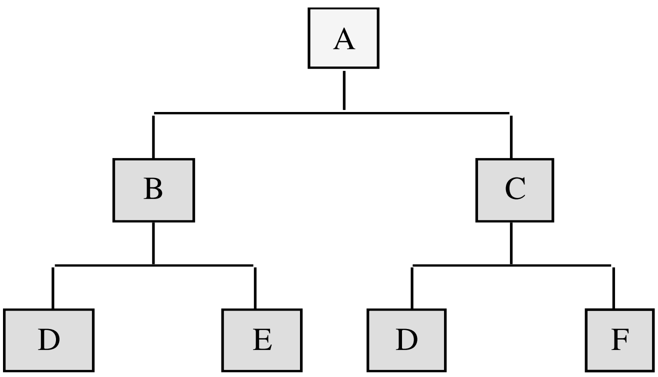
	1	2	3	4	5	6	7	8
Model 327	200			400		200	100	
Model 538		100	100		150		100	
Model 749			100			200		200

2. Bill of Materials

A bill of materials (BOM) file gives the complete product descriptions and documents quantities of each component, part, ingredient, or raw material needed to make that product or sub-assembly. It is also called as the product structure tree. A sample product structure tree is shown below.

For producing 1 unit of product A, 4 units of B and 2 units of C are required. For producing 1 unit of product B, 2 units of D and 1 unit of E are required. For producing 1 unit of product C, 3 units of D and 2 units of F are required Product Structure Tree.

Figure 2.25 - Product Structure Tree



NOTES

Explosion

If 20 nos. of product A is required then we require 80 nos. of B, 40 nos. of C, 280 nos. of D, 80 nos. of E and 80 nos. of F. This process of finding out the requirement of sub components based on the requirement of final product is known as Explosion.

3. Inventory status records

The following inventory status records goes as input to the MRP system

1. Item
2. Supplier
3. Lot size
4. Safety stock
5. Lead time
6. On hand inventory
7. Allotted
8. Level

i) Item**:** Name or number for the item being scheduled.

ii) Supplier**:** Name or number for the of the supplier for the scheduled item.

iii) Lot size**:** Several lot sizing techniques are available. Few of them are listed below.

a) Lot-For-Lot (LFL) ordering.

The lot-for-lot (LFL) is the simplest approach and it calls for producing in period t the net requirements for period t. The LFL approach minimizes the holding cost by producing just-in-time.

b) Economic Ordering Quantity (EOQ):

EOQ is a fixed quantity which is ordered whenever the inventory level reaches predetermined level.

$$Q = \sqrt{\frac{2 \times D \times Cs}{Cc\ (1- d/p)}}$$

Where,
Q – Economic ordering quantity
D – Annual demand
Co – Ordering Cost (Rs. /Order)

Cc – Holding cost (Rs./Unit/Unit time)

Economic Production Quantity (EPQ)

EOQ is a fixed quantity which is produced whenever the inventory level reaches a predetermined level.

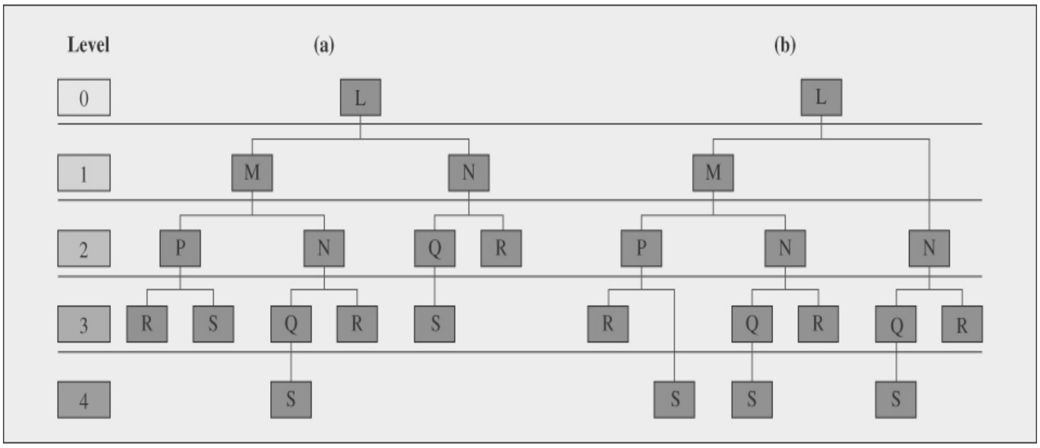
$$Q = \sqrt{\frac{2 \times D \times Cs}{Cc\ (1 - d/p)}}$$

Where,
Q – Economic Production quantity
D – Annual demand
Cs – Setup Cost (Rs. /Setup)
Cc – Holding cost (Rs./Unit/Unit time)
d – Demand rate
p – Production rate

There are also other algorithms available for lot sizing like Wagner-Whitin (WW) algorithm, Silver-Meal (SM) heuristic, part period balancing (PPB) heuristic etc. The lot sizing technique which incurs the lowest cost is chosen.

1. **Safety Stock**: It is the additional stock carried in order to protect against any uncertainty in demand.
2. **Lead time:** It is the time gap between placing an order and receiving the order.
3. **On hand inventory:** It is the actual quantity on hand during scheduling period.
4. **Allotted:** It the quantity of inventory allocated to other orders from the on hand inventory.
5. **Level:** It indicates the level occupied by the particular product/component in the product structure file.

Figure 2.26 – Levels in the product structure file



NOTES

If a component comes in more than one level then it should be assigned the lowest level code. For example, in the above figure R comes in both level 2 and level 3. But it should be assigned level code 3 as it is the lowest level.

MRP Process

The process of scheduling the Production of all items is done using an MRP Matrix. The MRP matrix is as shown below.

MRP Matrix

Table 2.8 – MRP matrix

Item: Low-Level Code: Lot Size: Lead Time:	PD	1	2	3	4	5
Gross Requirements						
Scheduled Receipts						
Projected on Hand						
Net Requirements						
Planned Order Receipts						
Planned Order Releases						

Gross Requirements is the anticipated usage of demand for each period.

Scheduled Receipts is the existing replenishment orders at the beginning of period.

Projected on Hand is the projected inventory status at the end of period after taking into account the inventory to be provided for safety stock and already allotted for other orders.

Net Requirements is the actual number of items to be provided and when it is to be provided. This is calculated taking into account scheduled receipts and projected on hand inventory.

Planned Order Receipts shows when actually net requirements are expected to be received.

Planned Order Releases shows when the order has to be released if the order has to be received as per planned order receipt.

Process Flow

Calculate the exact requirements for each item managed by the MRP system by the explosion process explained previously, and proceed as follows:

1. Retrieve level 0 item requirements (gross requirements) from the master schedule.
2. Use projected on-hand balances and schedule receipts to calculate net requirements. This process is called **Netting**.
3. Calculate when orders should be received to meet net requirements, developing planned-order receipts schedule.
4. Planned-order *release* schedule is calculated by **offsetting** the planned-order receipts by the items' lead times.
5. Repeat steps 1-4 for level 1 items.
6. Repeat steps 1-4 for all items in each subsequent level of the bill of materials.

MRP Output

The primary outputs of MRP are the following:

1. Recommendations of planned order releases.
2. Rescheduling notices changing open-order due dates.
3. Notices to cancel or suspend open orders.
4. Item-status-analysis backup data.
5. Future planned order schedules.

A variety of secondary or byproduct outputs can be generated by MRP at the user's option. It is not practical to list and describe all possible outputs and formats generated by MRP found in industry; MRP lends itself to tailoring, individualization, and infinite modification of outputs. MRP files (database), particularly inventory status records, contain a wealth of data, providing almost unlimited opportunities for the supplying of these data to a whole spectrum of possible outputs. Here are some of the common secondary outputs:

1. Exception notices, reporting errors, incongruities, and out-of-limits situations.
2. Inventory-level projections (inventory forecasts).
3. Purchase commitment reports.
4. Tracers to demand sources (pegged requirements reports).
5. Performance reports for people and functional groups.

Six categories of outputs by functional use are:

1. Inventory order action.
2. Replanning order priority.

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3. Safeguarding priority integrity.
4. Capacity requirements planning.
5. Performance control.
6. Reporting errors, incongruities, and out-of-limits situations.

Inventory order action outputs occur when planned orders appear in current time-buckets. Other types of order action are increases, reductions, or cancellations of order quantities.

Re-planning order priority outputs alert inventory planners to cases of divergence between open-order due dates and dates of actual need, resulting from changed timing of net requirements.

Outputs to help **Safeguard priority integrity** aims at keeping order priorities honest, revealing inventory status problems caused by overstated MPS. Some companies use these reports to provide guidance for planners when accepting customer orders for guaranteed delivery. A “trialfit” of the order as an MPS item enables a net change MRP program to determine potential component shortages. If the order does not fit (too many shortages), the planner can recommend an alternative delivery date.

Capacity requirements planning outputs of MRP are open and planned shop orders in individual time periods, which are input into the load projection program. To keep load projections up-to-date and valid, they must be recomputed as MRP order schedules change.

Performance control outputs are comparisons of MRP plans with actual performance, enabling management to monitor the performance of inventory planners, buyers, the shop, suppliers, and cost accounting.

Outputs reporting errors, incongruities, and out-of-limits situations are called exception or action reports. Some examples:

1. Date of gross requirement is beyond the planning horizon.
2. Number of digits of quantity in gross requirement exceeds size of the field.
3. Planned order is offset into a past period but placed in current period.
4. Number of digits of quantity of open order exceeds size of the field.
5. Number of digits of quantity of net requirements exceeds size of the field.
6. Number of digits of quantity of receipt overflows size of quantity-on hand field.
7. Due date of open order is outside of planning horizon.
8. Allocated on-hand quantity exceeds current quantity on hand (potential shortage).
9. Past-due gross requirement has been included in the current period.

NOTES

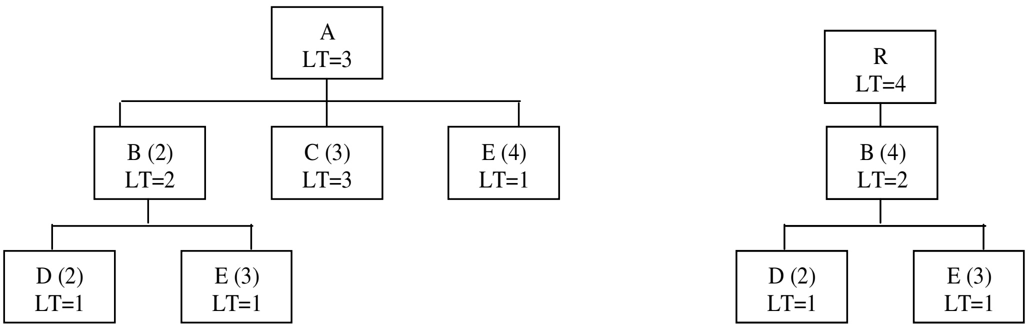
In addition to such exception reports, individual exception messages can be generated at the time inventory transaction are entered, listing reasons for transaction rejections. Some typical messages are

1. Part number is nonexistent.
2. Transaction code is nonexistent.
3. Part number is incorrect (using self checking digits).
4. Actual receipt exceeds quantity of scheduled receipt by x percent (test of reasonableness).
5. Quantity of reported scrap exceeds quantity on hand.
6. Quantity of disbursement exceeds quantity on hand.
7. Order being released exceeds planned quantity.

Sample MRP Problem:

Orders have been received for 20 units of product A and 50 units of product R with the product structures shown below for period 8. The on hand stock levels are A=1, R=4, B=74, C=19, D=190 and E=160. What is the low level code for each item? If the components are ordered as required (no fixed lot sizes), what should be the size of each order? When should the orders be released for each item?

Figure 2.27



Solution
Table2.8

Item	Low Level Code
A	0
R	0
B	1
C	1
D	2
E	2

NOTES

Figure 2.28

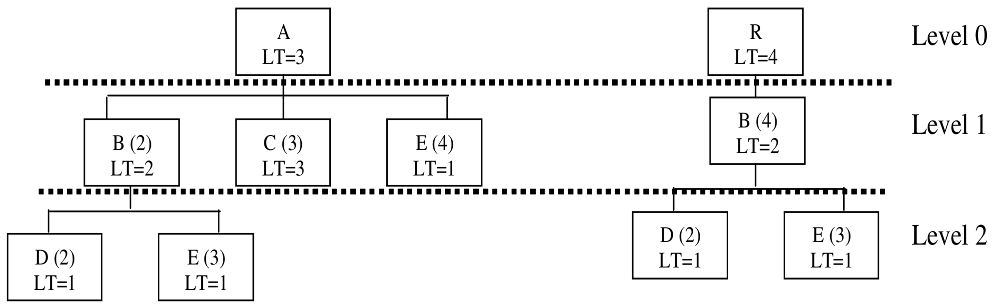


Table 2.9

Item	Lot Sizing	Lead time	Safety Stock	Allotted	Level	Period	PD	1	2	3	4	5	6	7	8
						Gross Requirements									20
						Scheduled Receipts									
A	Lot for Lot	3	—	—	0	Projected on Hand	1	1	1	1	1	1	1	1	1
						Net Require-ments									19
						Planned Order Receipt									19
						Planned Order Release						91			

Table 2.10

Item	Lot Sizing	Lead time	Safety Stock	Allotted	Level	Period	PD	1	2	3	4	5	6	7	8
						Gross Requirements								50	
						Scheduled Receipts									
R	Lot for Lot	4	—	—	0	Projected on Hand	4	4	4	4	4	4	4	4	4
						Net Require-ments									46
						Planned Order Receipt									46
						Planned Order Release					46				

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Table 2.11

Item	Lot Sizing	Lead time	Safety Stock	Allotted	Level	Period	PD	1	2	3	4	5	6	7	8
						Gross Requirements					184	38			
						Scheduled Receipts									
B	Lot for Lot	2	—	—	1	Projected on Hand	74	74	74	74	74	0			
						Net Require-ments					110	38			
						Planned Order Receipt					110	38			
						Planned Order Release			110	38					

Table 2.12

Item	Lot Sizing	Lead time	Safety Stock	Allotted	Level	Period	PD	1	2	3	4	5	6	7	8
						Gross Requirements						57			
						Scheduled Receipts									
C	Lot for Lot	3	—	—	1	Projected on Hand	19	19	19	19	19	19			
						Net Require-ments						38			
						Planned Order Receipt						38			
						Planned Order Release			38						

Table 2.13

Item	Lot Sizing	Lead time	Safety Stock	Allotted	Level	Period	PD	1	2	3	4	5	6	7	8
						Gross Requirements			220	76					
						Scheduled Receipts									
D	Lot for Lot	1	—	—	2	Projected on Hand	190	190	190	0					
						Net Require-ments			30	76					
						Planned Order Receipt			30	76					
						Planned Order Release			30	76					

NOTES

Table 2.14

Item	Lot Sizing	Lead time	Safety Stock	Allotted	Level	Period	PD	1	2	3	4	5	6	7	8
E	Lot for Lot	1	—	—	2	Gross Requirements			330	114		76			
						Scheduled Receipts									
						Projected on Hand	160	160	160	0	0	0			
						Net Require-ments			170	114		76			
						Planned Order Receipt			170	114		76			
						Planned Order Release		170	114		76				

Review Questions:

1. List input of MRP system.
2. List two MRP outputs.

2.9 MANUFACTURING RESOURCE PLANNING (MRP II)

2.9.1 Introduction

Till the early sixties, reorder point (ROP) systems was used by many manufacturing organizations. In this system the component stocks were reordered whenever stock fell to a pre-defined reorder level. Components were often ordered when not actually needed, and because of which ROP systems resulted in very high inventory levels.

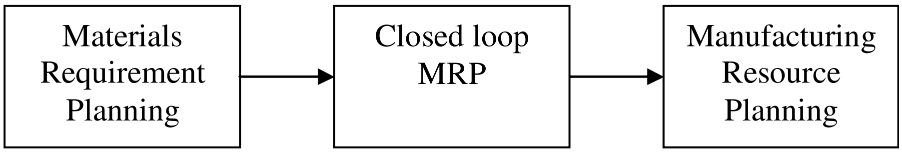
In the sixties, customers became demanding, competition became tougher and the interest rates began to increase. This made organizations to realize the necessity to develop a much better response to the customer needs. At the same time the increase in interest rates made money tied up in inventory into a serious financial burden for manufacturing organizations.

In this period, computers were brought into planning and production systems. As a result, several new manufacturing systems were developed. They were.

- Material requirements planning systems.
- Heavily reliant on computers and most frequently applied to batch or mass production. Comprising of:
- Material requirements planning (MRP or MRP I).
- Closed loop material requirements planning (Closed Loop MRP).
- Manufacturing resource planning (MRP II).

- Just-in-time (JIT).
- Optimized Production Technology / Theory of Constraints (OPT/TOC)
- Project control
- Evolution of Manufacturing Resource Planning (MRP II)

Figure 2.29- Evolution of Manufacturing Resource Planning (MRP II)



2.9.3 Closed Loop MRP System

In an open loop MRP system the plans are sent to buyers and production personnel but it is not possible to get feedback. As a result of which the adjustments could not be made to plans in order to keep schedules valid. For example, it assumed that infinite capacity was available, and that suppliers always delivered correctly and on time. And when there is a change in sales demand it will take excessive amount of re-planning.

Also, much of the demands from other sources are left out of the system and shortages become inevitable. Material requirements planning generates valid schedule that follow logically from the demand. But after planned orders are launched, some of the planning factors may begin to stray off course. Some of the examples that cause problem because of using MRP systems are shown below:

- ♦ Lead time estimates differ if: machine breaks down, deliveries are delayed, goods are damaged, power fails etc.
- ♦ If the system plans for 1000 of a component but 200 fail a quality inspection, this shows that the orders are arrived on time but there will be a shortage of material.
- ♦ The demand that drives material requirements planning consists of both forecast orders and actual customer orders. The forecasts may turn out to be wrong and customers may change their actual orders, for example, by asking for earlier or later delivery. This throws out all component orders.

In summary, ‘open loop’ material requirements planning could result in some or all of these problems:

- Uncontrollable costs.
- Late deliveries to customers.
- Late deliveries from suppliers.
- Unplanned overtime/offloading.

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- High work-in-progress levels.
- Mismatched inventories.
- Over- or under-utilized resources.
- Disruptions on the shop floor.
- Many full-time expeditors.
- Customer complaints.
- High 'past dues'.
- Long queues.

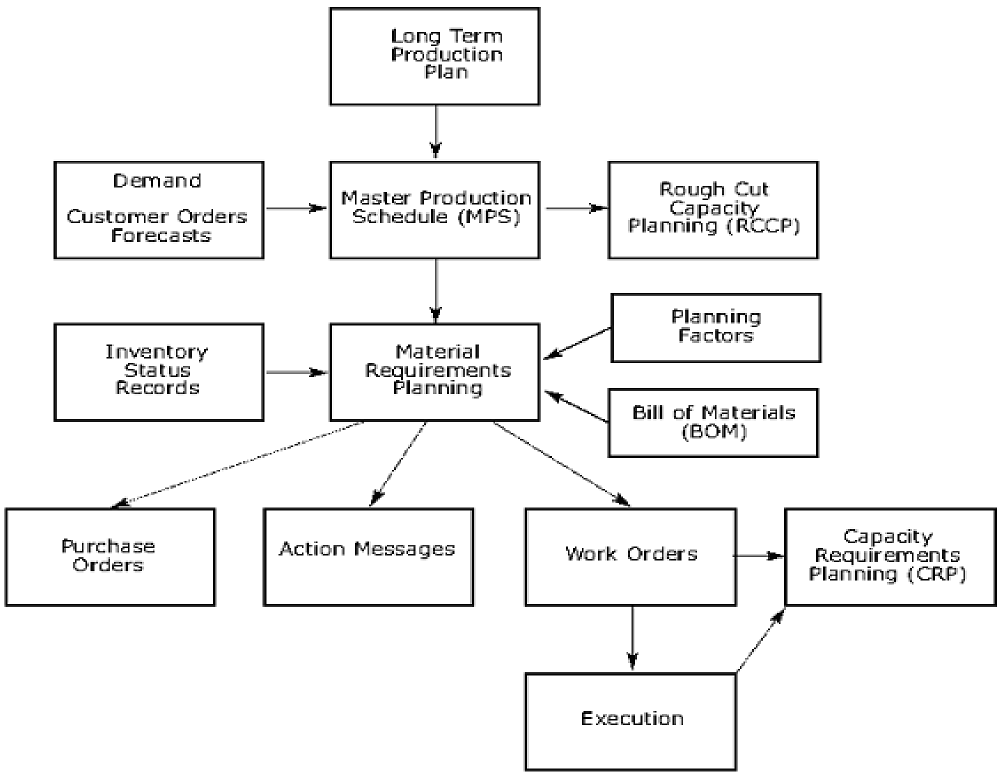
This is clearly not a list that any manufacturing organization could regard as acceptable.Something had to change, and so open loop MRP evolved into closed loop MRP.

Closed loop MRP

Material requirements planning is useful but due to the problems that are faced by the organization after implementation of MRP and lack of awareness of other related production and business functions, the organization started to shift towards closed loop MRP system. The diagram below shows the much wider data horizon that is now opened up for organizations which have started using better information technology to upgrade their MRP system.

Closed loop MRP

Figure 2.30 – Closed loop MRP



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Closed loop MRP has made feedback possible by including new functions such as file control, a master production schedule, rescheduling actions and shop floor control. It thus 'closed the loop', overcoming the fundamental weakness of 'open loop' material requirements planning.

The closed loop diagram shows several additions to the open loop diagram:

- The long-term production plan. This feeds information into the master production schedule about the organization's long-term manufacturing expectations.
- The master production schedule passes information to a separate rough cut capacity planning module, which estimates the amount of work achievable in a given time period.
- Orders generated by MRP are split into purchase orders and work orders.
- Manufacturing orders are passed to the capacity requirements planning module to see if there is sufficient labor and machine time available to carry them out in the time proposed by the master production schedule. This is a more detailed evaluation than rough cut capacity planning; it looks at individual work centers and their proposed workloads.
- The shop-floor execution phase is also shown; this is used to control the on-time completion of work orders.

2.9.4 Manufacturing Resources Planning (MRP II)

Manufacturing resources planning (MRP II) is an extended form of closed loop MRP that also incorporates strategic planning processes, business planning, and a number of other business functions such as human resources planning, profit calculation and cash flow analysis. MRP II uses the master production schedule as the basis for scheduling capacity, shipments, tool changes, some design work, and cash flow. Hence it requires several additions to the reference files. One is a bill of resources, which details key resources needed to produce one unit of product. These resources may include labour, machinery, tools, space and materials.

The MRP II system can use the bill of resources to project shortages at specific times, giving departments advance notice of required remedial action: for example, of the need to hire or train labour. MRP II can also project needs for support resources; for example, design engineering support if a customer order entails prior design work. This additional resource is added to the bill of resources. Given still more reference data, MRP II can keep track of tool wear and recommend when to replace or reshape tooling. It can also keep track of machine loads and project machine capacity shortages, which may signal a need for more machines or a subcontractor.

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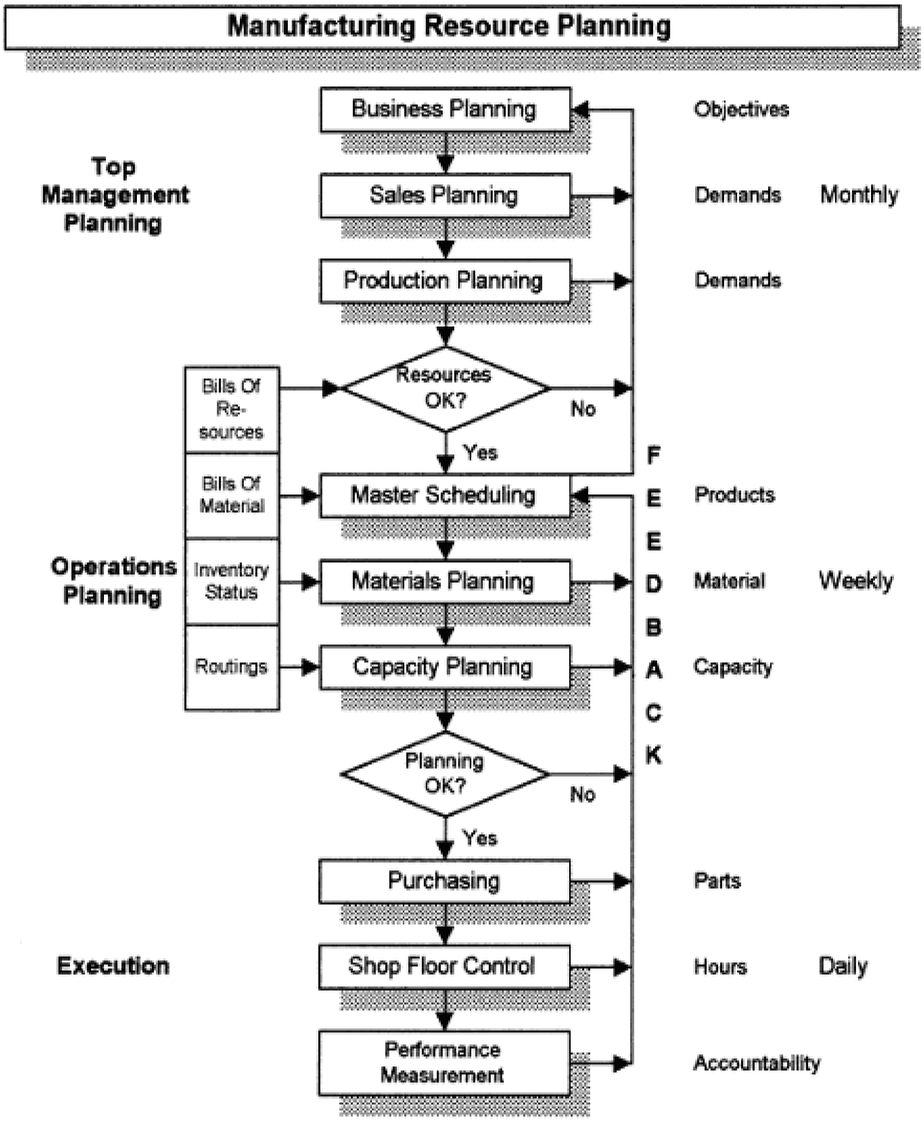
For financial planning, MRP II treats cash flow almost like materials. The MPS is first exploded into component parts requirements; the system then calculates the cost and payment dates of all planned order releases, effectively creating a cash flow forecast. This includes not just payments to suppliers, but also wages, power and other consumables associated with production. Cash outflows may be projected for a year or more by expense category, work centre or department, making budgeting much simpler than it would be without an MRP II system.

Figure 2.31 - Framework of MRP II



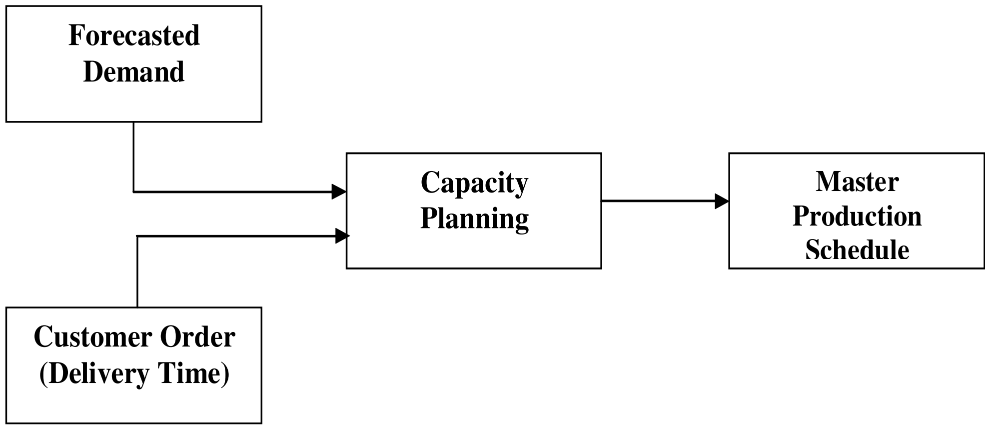
2.9.3 Master Production Schedule

The MPS is a statement of the planned production of finished products that will meet the demand on time, within the organization's capacity. The master production schedule expresses. What we intend to make, how much we intend to make and when we intend to make.

The demand for end items is scheduled over a number of time periods and recorded on a master production schedule (MPS).The MPS is developed from forecasts and firm customer orders for end items, safety stock requirements and internal orders. MRP takes the master schedule for end items and translates it into individual time-phased component requirements.

Overview of Master Production Schedule:

Figure 2.32 - Overview of Master Production Schedule



Capacity Planning:

Capacity planning essentially involves the following categories.

Resource Requirements Planning*:*

Resource requirements planning refers to the planning of the overall capacities of the firm. This planning is done to validate the aggregate production plans of the firm.

Rough Cut Capacity Planning (RCCP):

Rough cut capacity planning (RCCP) involves planning capacities at key / bottleneck work centers and broadly balancing workloads. It thus validates the MPS. Material requirements planning (MRP) uses a master production schedule (MPS) of end items to determine the quantity and timing of component part production. MRP is capacity insensitive; it implicitly assumes that sufficient capacity is available to produce components at the time they're needed.

A problem commonly encountered in operating MRP systems is the existence of an overstated MPS. An overstated master production schedule is one that orders

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more production to be released than production can complete. An overstated MPS causes raw materials and WIP inventories to increase because more materials are purchased and released to the shop than are completed and shipped. It also causes a buildup of queues on the shop floor. Since jobs have to wait to be processed, actual lead times increase, causing ship dates to be missed. As lead times increase, forecast accuracy over the lead-time gets affected because forecasts are more accurate for shorter periods than for longer ones. Thus, overstated master production schedules lead to missed due dates and other problems. Validating the MPS with respect to capacity is an extremely important step in MRP. This validation exercise has been termed **rough cut capacity planning (RCCP)**.

For example: consider the man hour requirement for three components over a three week period as follows:

Table 2.15

	Week 1	Week 2	Week 3
Component A	70	70	70
Component B	100	100	120
Component C	80	75	80

Let us now check the total man hours required to produce this master production schedule. From the above illustrated resource requirements, a rough cut analysis can be done as follows:

Table 2.16

	Week 1	Week 2	Week3
Required standard hours	250	245	270
Available standard hours	250	250	250
Negative deviation			-20
Positive deviation		+5	

RCCP DECISIONS

In this section, we discuss how to determine the amount of capacity that is available, how to compare the capacity available to the capacity required and the options that exist for adjusting the capacity available and/or the capacity required.

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Determining the Capacity Available

The plastic molding department of Al's Lamps, presented in the previous section, has three plastic molding machines. Since Al's works one eight-hour shift each day and there are 21 working days in an average month, it might seem that the capacity available to the plastic molding department is 504 hours per month (3 machines times 8 hours/day/machine times 21 days/month).

However, two additional factors must be considered. First, the plastic molding machines may not be available all the time. The machines may break down, the worker may be absent, and the mold needed or the material needed may not immediately be available. Second, there must be an adjustment between the time standard average and the actual average production rate of the department. The first adjustment factor is known as utilization. Utilization is a number between 0 and 1 that is equal to 1 minus the proportion of time typically lost due to machine, worker, tool, or material unavailability. The second adjustment factor is known as efficiency. Efficiency is formally defined to be the average of standard hours of production per clock hour actually worked. If a time standard is exactly right, efficiency is 1. If the time actually required to perform the work is less than the standard, efficiency is more than 1. If the time actually required to perform the work is more than the standard, efficiency is less than 1. As mentioned previously, time standards tend to be slightly pessimistic due to continual improvement in production methods.

Capacity available is found by multiplying time available times utilization and times time efficiency:

Capacity Available = Time Available x Utilization x Efficiency

Assume that for the plastic molding department of Al's Lamps, utilization is 0.756 and efficiency is 1.05. The time available in a month having 168 working hours (21 eight-hour days) is 504 (3 machines times 168 hours/month/ machine). Thus,

Capacity Available = 504 x 0.756 x 1.05 = 400 hours (rounded to the nearest hour).

When capacity is inadequate, four basic options are available to increase capacity: overtime, subcontracting, alternate routing, or adding personnel. If no combination of the four options can provide sufficient capacity, the MPS will have to be reduced. Options to adjust capacity required or available are discussed next.

- **Increase Capacity**
  - Additional shifts
  - Overtime
  - Additional resources

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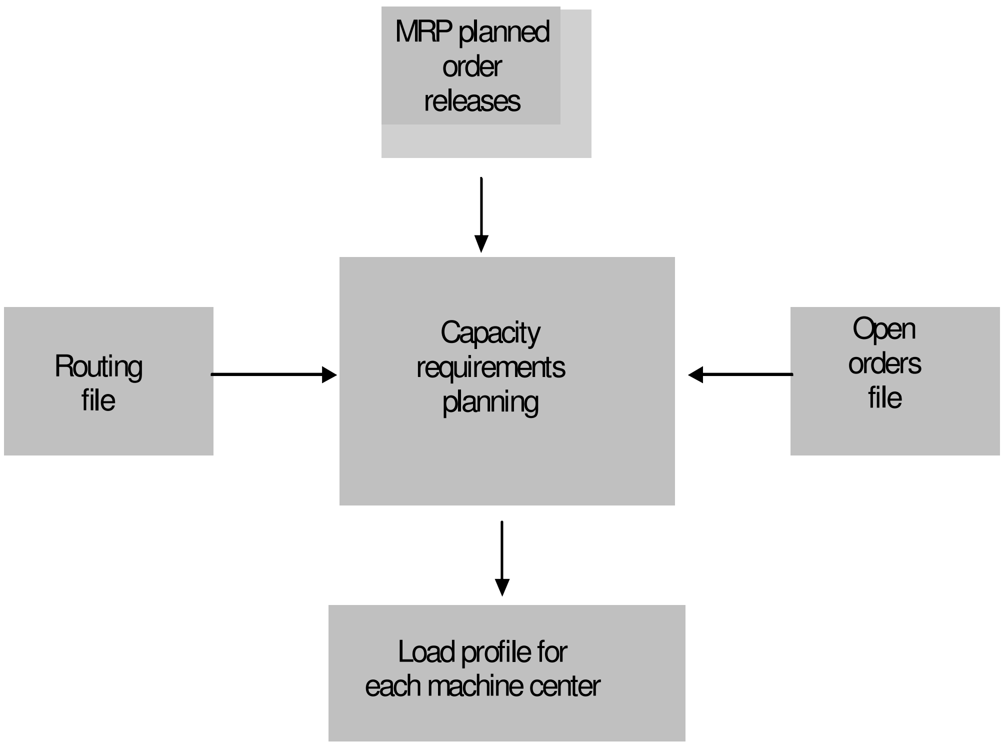
- **Reduce Load**
  - Subcontract
  - Reduce lot sizes if possible
- **Redistribute Load**
  - Use alternate work centers or routings if possible
  - Shift production to earlier periods that have additional capacity
  - Temporarily use safety stocks and shift load to later period
- **If all else fails, revise MPS**

2.9.4 Capacity Requirements Planning

Capacity requirements planning (CRP) is a computer-based extension of the MRP process that uses the results of MRP along with detailed production information and labor information to calculate planned workloads. It is a detailed capacity analysis that helps in validating the MRP schedule. CRP arises mainly due to batching of production work orders in the course of MRP. It is thus a computerized system that projects load from material requirements plan.

CRP Inputs & Outputs

Figure 2.33



Key Inputs

• Schedule of open orders and planned order releases (from MRP).

A typical example would be as follows:

Table 2.17

Release date	Due date	Planned orders	Number of batches of 20
week 5	week 7	40	2
week 8	week 10	80	4

• **BOM** with routing data:

A typical example would be as follows:

Table 2.18

Part D routing (hours)

Operation	Work center	Run time	Setup time	Move time	Queue time	Total time	Rounded time
1	201	1.6	0.5	0.4	2.6	5.1	5.0
2	208	1.5	0.3	0.2	2.8	4.8	5.0
3	204	0.1	0.1	0.3	0.6	1.1	1.0
4	209	1.2	0.8	0.3	2.3	4.6	5.0

Total lead time 16 hr (2 days)

Part E routing (hours)

Operation	Work center	Run time	Setup time	Move time	Queue time	Total time	Rounded time
1	201	1.1	0.4	0.3	1.8	3.6	4.0
2	204	0.2	0.3	0.2	0.5	1.2	1.0
3	205	1.2	0.1	0.4	1.5	3.2	3.0

Total lead time 8 hr (1 day)

• **Work center data**

A typical example would be as follows:

Table 2.19

Work centre	201
Queue time	2.5 hours
Available capacity	440.0 hours

• **Work order status**

Key Outputs

• Work center load report.

• Possible *revised* schedule of planned order releases.

NOTES

2.9.5 Forward Scheduling And Backward Scheduling

Forward scheduling:

In forward scheduling, we identify the earliest start date for the operation in question through consideration of the planned order release date generated by MRP. We then use the lead time to calculate the completion date. If the completion time is prior to the due date then we have slack time available. If completion date is after due date, we have a delay.

Backward scheduling:

In backward scheduling, we identify the due date for the operation in question and use the operation lead time to calculate the latest operation start date. If the latest start time is after the earliest start date then we have slack time available. If the operations start time is prior to the earliest start date then we have negative slack.

An Illustration of Capacity Requirements Planning:

Consider a component-A which has a planned order as follows:

Table 2.20

Release date	Due date	Planned orders	Number of batches of 20
week 5	week 7	60	3

This component has to undergo three process namely assembly, painting and inspection. the data for these work centers is as follows:

Table 2.21

Work center	Assembly
Queue time	10.0 hours
Available capacity	60.0 hours
Set up time	0.40 hours
Processing time	0.30 hours
Transport time	1.30 hours

Table2.22

Work center	Painting
Queue time	18.0 hours
Available capacity	60.0 hours
Set up time	0.60 hours
Processing time	0.45 hours
Transport time	1.30 hours

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Table 2.23

Work center	Inspection
Queue time	42.0 hours
Available capacity	60.0 hours
Set up time	0.04 hours
Processing time	0.30 hours
Transport time	1.30 hours

Calculation of department loads:

Assembly department:

Load from component-A

(Batch size X processing time) + Set-up

60 X 0.30 + 0.4 = 18.4 Hours

Painting department:

Load from component-A

(Batch size X processing time) + Set-up

60 X 0.45 + 0.6 = 27.6 Hours

Inspection department:

Load from component-A

(Batch size X processing time) + Set-up

60 X 0.30 + 0.04 = 18.04 Hours

Calculations of operation lead time:

Operation lead time is calculated as

Operation lead time = Load from component + Queue time + Transport time

For assembly,

Operation lead time = 18.4 + 10 + 1.3 =29.7

For Painting,

Operation lead time = 27.6 + 18 + 1.3 =46.9

For Inspection,

Operation lead time = 18.04 + 42+ 1.3 =61.34

NOTES

Now we use backward scheduling .The inspection has a lead time of 61.34 hours and hence is loaded for the due date, which is week 7.Therefore the previous operation (painting) is scheduled for the previous week (week 6).Painting only has a lead time of 46.9 hours, which means the assembly operation can be scheduled for completion in week 6.

These load projections can be represented as follows:

Figure 2.34

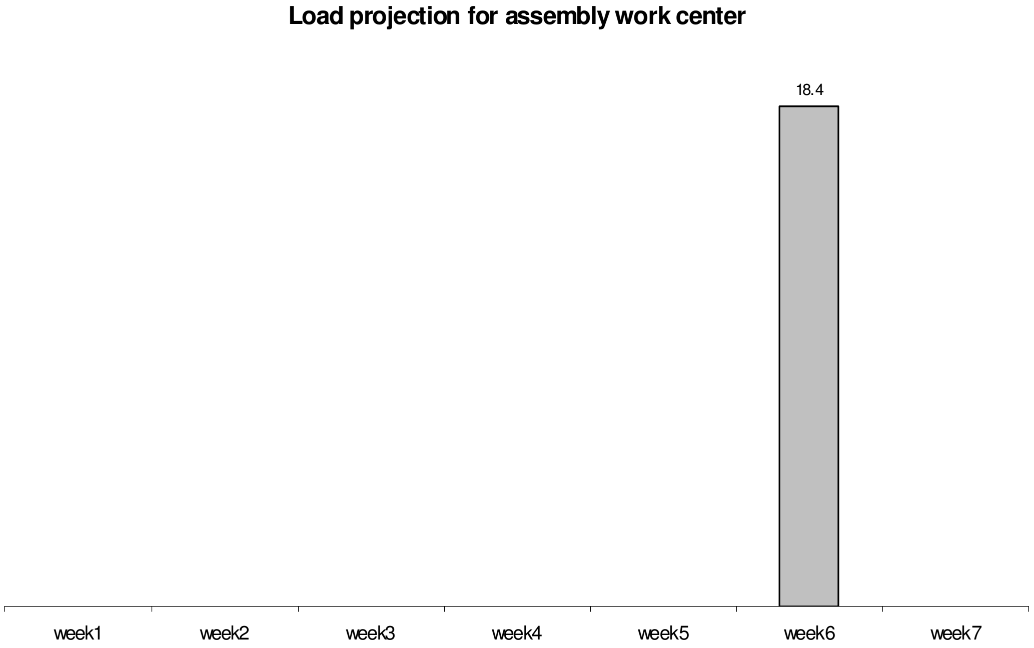


Figure 2.35 -

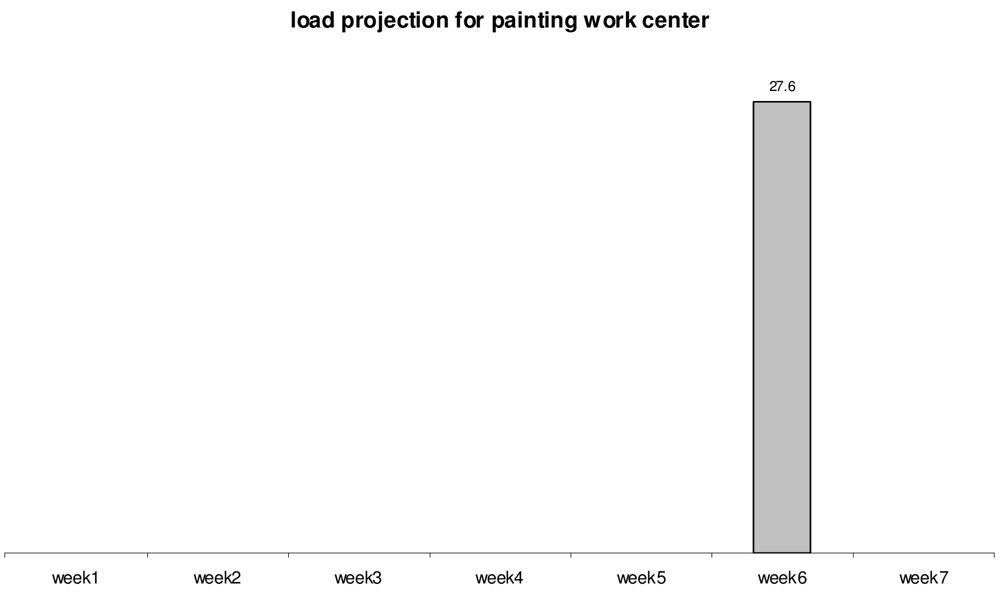
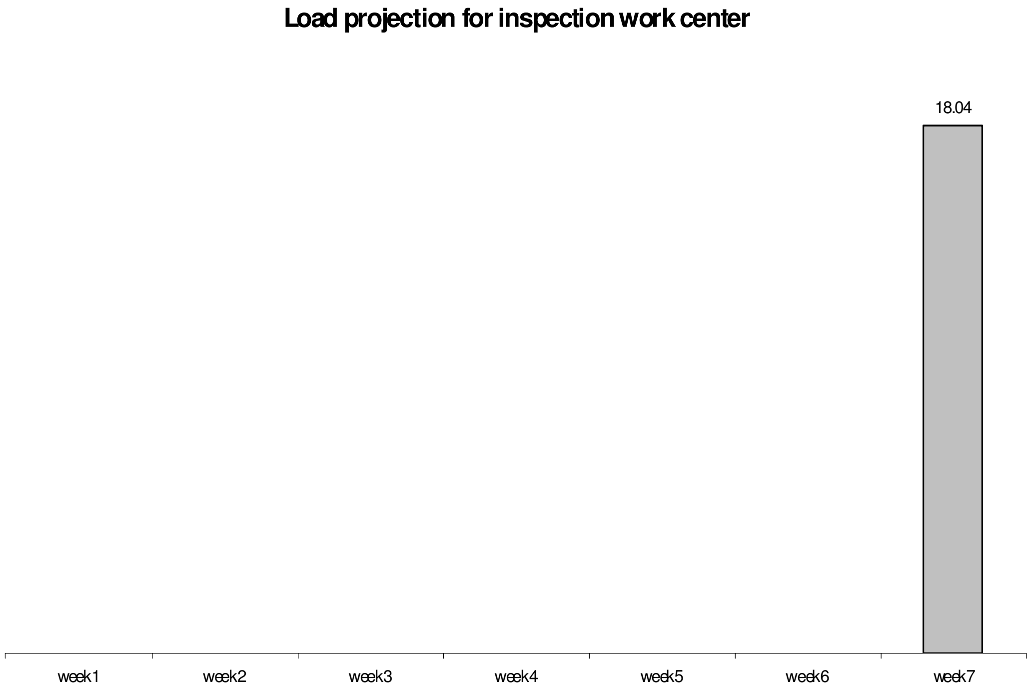


Figure2.36



Shop floor control

The system is provided with information on how many units were sent onwards and the date as each work centre completes a job. This information enables the MRP system to provide each work centre with daily notices of priority changes. After rescheduling, new due dates and quantities go out to the factory and supplier companies, who must act on them so that the previous schedule, with the jobs in progress, is updated. The shop floor control thus provides information on the reschedules with the help of which the existing schedules can be updated.

Production Activity Control (PAC)

PAC, Production Activity Control, is concerned with converting plans into action, reporting the results achieved and revising plans and actions as required achieving desired results. Thus, PAC converts plans into action by providing the required direction. This requires the appropriate prior master planning of orders, work force personnel, materials, and capacity requirements. They are useful in the management of lead-time, queue length, work center idle time, and scheduled order completion. The three primary functions of PAC

- Order release
- Dispatching
- Progress reporting

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Order Release

Order release initiates the execution phase of production; it authorizes production and/or purchasing. The planned order becomes a released (open) order. Placement of a purchase order or the initiation of manufacturing follows shortly. Order release planning may take place until the moment of order release.

Authorization of order release is based on the planned orders in the MRP output, the current priority, the availability of materials and tooling, and the loads specified by I/O planning. Release of an order triggers the release of the following:

1. Requisitions for material and components required by the order. If some of these items are not required immediately and have not been allocated previously, they are allocated now.

2. Production order documentation to the plant. This documentation may include a set of both engineering drawings and manufacturing specifications and a manufacturing routing sheet.

3. Requisitions for tools required in the first week or so of production. Tooling, including tapes for numerically controlled machines, required in later operations is reserved for the appropriate period. Tooling can be included in the master production schedule and the bill of material. Its availability is thus coordinated with material and equipment availability.

The time required to deliver production order documentation, tooling and materials to the first operation is included in the normal planned lead time for the order. An order is released by adding it to the dispatch list.

Dispatching

Dispatching informs first-line supervision of the released orders and their priority, that is, the sequence in which orders should be run. This information can be transmitted via a hard copy (handwritten, typed, or computer printout) or via video output on a cathode ray tube (CRT). In a job shop a dispatch list should be prepared for each work center with the frequency of updating depending on the typical order-processing time. If orders take a day or less to process, dispatch lists usually are prepared daily. If orders take a few days, lists may be prepared weekly with midweek revisions handled on an exception basis with on-line processing.

In a flow line process environment, a single list indicating the rate of flow (or in a batch flow line, the sequence in which orders are to be started) will control work on the entire line, which may be viewed as a single work center. An example of simple dispatch list information identifies the date, the plant, and the work center; it includes the work center capacity; and it lists the orders, their quantity, their capacity requirements, and their priority. Orders usually are listed in descending priority for a specified period.

The list also may include jobs at upstream work centers to provide the supervisor with information concerning orders that will arrive shortly and an indication of their priority upon arrival. A computerized system may produce relative rankings on the basis of criteria such as critical ratio and earliest due date, as described earlier, but review by a planner is required to determine if other considerations are overriding.

The planner determines the final dispatch list ranking of orders on the basis of the multiple criteria including a formal priority index such as, the critical ratio or the due date, input control at downstream work centers, the availability of tooling, the status of other parts required in the same assembly, energy consumption patterns, and sequencing and assignment criteria.

Production Reporting

Reports describing the actual production status are necessary for control. Dynamic response to the changing conditions is possible only if timely, accurate, and adequate information is available. The information must enable management to take meaningful corrective action concerning production schedules.

The production environment influences the design of the production reporting system. Reporting in a line flow environment with long production runs, may take place on an exception basis with feedback occurring only when the output rate falls below an acceptable level. All reporting systems should have an exception reporting capability to inform management whenever machine failure, material shortages, or similar events threaten planned output.

2.9.6 Benefits of MRP II

In the narrow sense, the main benefit of MRP II is its ability to generate valid schedules and keep them valid. But valid schedules have broader benefits for the whole organization. These include, more or less in order of importance:

1. Improved on-time completion

A typical manufacturing organization using MRP II should be able to achieve on-time completion rates of 95 per cent or more, because completion of a parent item is less likely to be delayed for lack of a component. On-time completion helps improve customer service.

2. Reduced inventories

Inventory falls - typically by 20-35 per cent - because parts are not ordered until needed.

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3. Capacity requirements planning data

Work centre capacity requirements can be planned for many periods into the future.

4. Improved direct labour productivity

Fewer shortages mean significantly less lost time and overtime, and less disruption to accommodate shortage-list jobs.

5. Improved productivity of support staff

MRP II cuts expediting (or 'firefighting') and allows more time for planning. For example, purchasing can start looking for alternative or better suppliers; materials management can plan inventory needs better.

6. Total business planning

The ability to use one common set of data to help plan and control the whole business.

2.9.7 Drawbacks of MRPII

Though Manufacturing Resource Planning has a number of benefits, it has a few limitations too. They are:-

- MRP II system is complex.
- MRP II implementation programmer, takes a lot of time, effort and commitment at all levels of the organization to set up a successful MRP II system.

The benefits, however, should very quickly make the exertion worthwhile.

Review Questions:

1. MRPII stand for?
2. List the various phases of evaluation of MRPII
3. Discuss the input requirement of the capacity requirement planning.
4. What is dispatching?
5. List any two benefits of MRP

2.10 ENTERPRISES RESOURCE PLANNING

It is a system which integrates all the procesess and data of an organization. It uses the hardware and software to integrate the activities of manufacturing, supply chain, Financials, Customer Relationship Management (CRM), Human Resources and Warehouse Management.

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2.10.1 Need for ERP

In the past, then available software applications that don't talk to each other and do not effectively interfaces, so the organizations were in the pursuit of identifying a new software to eliminate the above limitation that result in the invention of ERP system.

ERP acts as a single database that includes all data for the software modules, which would include manufacturing, supply chin management, finance, projects, customer relationship management, data warehouse. This is shown in figure 2.36.

Manufacturing:

Engineering, Bills of Material, Scheduling, Capacity, Workflow Management, Quality Control, Cost Management, Manufacturing Process, Manufacturing Projects, Manufacturing Flow.

Supply Chain Management:

Inventory, Order Entry, Purchasing, Product Configurator, Supply Chain Planning, Supplier Scheduling, Inspection of goods, Claim Processing, Commission Calculation etc.

Finance:

General Ledger, Cash Management, Accounts Payable, Accounts Receivable, Fixed Assets.

Projects:

Costing, Billing, Time and Expense, Activity Management

Human Resources:

Human Resources, Payroll, Training, Time & Attendance, Benefits

Customer Relationship Management:

Sales and Marketing, Commissions, Service, Customer Contact and Call Center Support etc.

Data Warehouse:

Various Self-Service interfaces for Customers, Suppliers, and Employees.

The framework of ERP is shown in the figure 2.36

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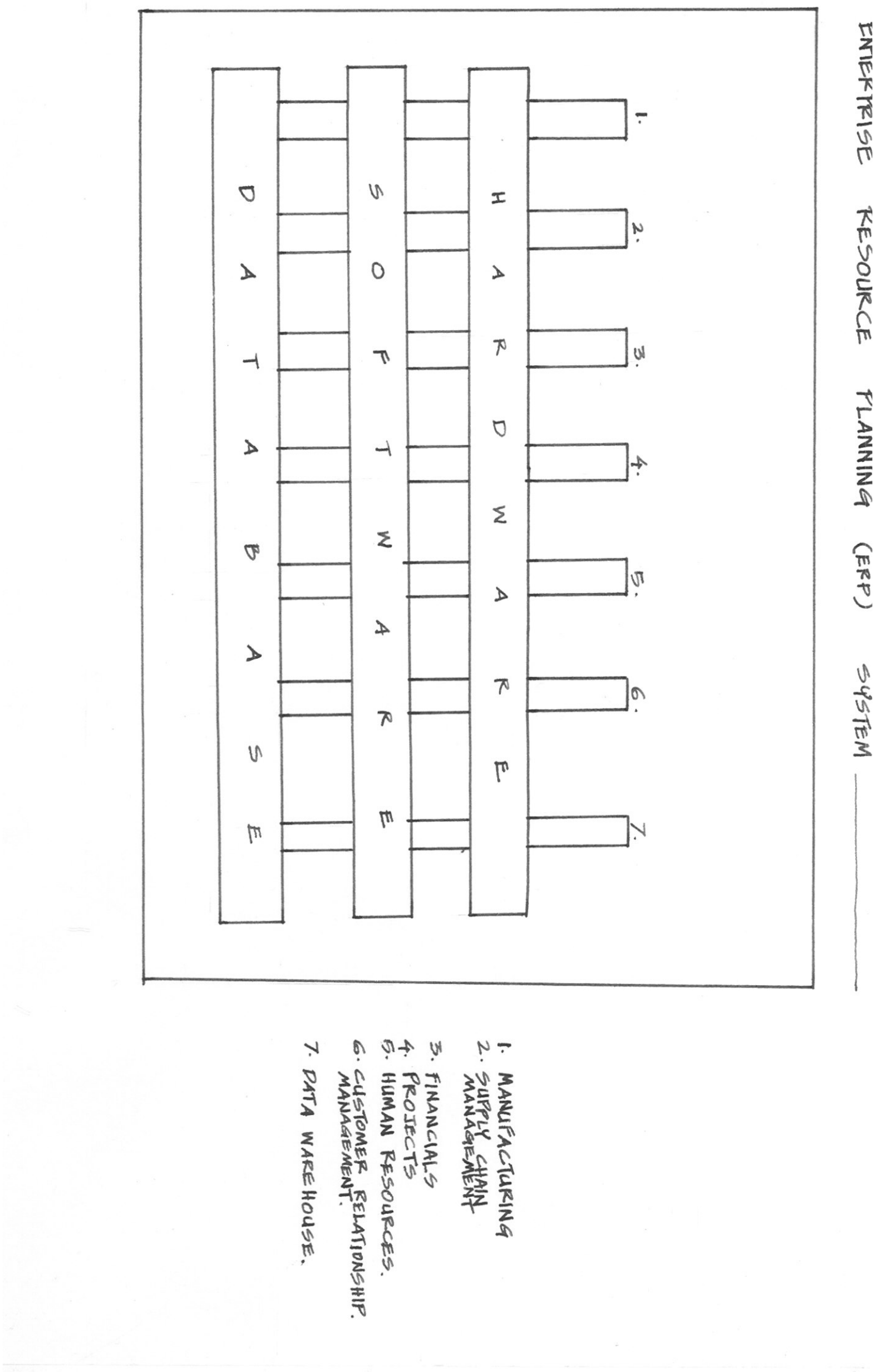
Figure 2.36 - ERP System



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2.10.2 Evolution of ERP:

MRP – Material Requirement planning focused mostly in the plant production level, started, emphasizing the controlling of inventory for the dependent items. It acts as a production scheduling system also. Because of change in business scenario like more competition, more Global suppliers, warehousing, Global product demand, at different count, changing environment business currency complexities etc. Focus has been shifted from beyond the production level, to include all the activities that results in the development of manufacturing resource planning, MRP II includes the sub modules manufacturing, logistics, distribution, inventory, shipping, involving and accounting for a company. Then further, improvement in the MRP II leads to the birth of ERP.

2.10.3 Advantages of ERP system

1. ERP effectively interfaces all the activities of the organization.

2. Computer security is included within an ERP to protect against both outsider crime, such as industrial espionage and insider crime, such as embezzlement.

2.10.4 Disadvantages of ERP system

1. High investment required in buying and implementing the ERP system.
2. Problem due to a lack of corporate policy protecting the integrity of the data in the ERP system and how it is used.

2.10.5 Limitations of ERP include

1. There are compatibility problem with the various legacy system of the implementing organizations.
2. Hesitance in sharing sensitive internal information between departments can reduce the effectiveness of the software.
3. The blurring of company boundaries can cause problems in accountability, lines of responsibility, and employee morale.
4. ERP system can be difficult to use
5. ERP system is considered to be too rigid and too difficult to adapt to the specific work flow and business process of some companies.
6. Annual license renewal change is constant irrespective of the size of the company using the ERP.
7. Re-engineering of business processes to fit the "Industry Standard" prescribed by the ERP system may lead to lots of competitive advantages.
8. Customization of ERP software is limited.
9. The success of an ERP system depends on the skill and experience of the workforce.
10. Lack of training to the workforce result in failure of the ERP system.

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Review Questions:

1. What does ERP stands for?
2. List the Major phases in evaluation of ERP.

2.11 E-BUSINESS AND E-COMMERCE

Like any emerging field, e-business is changing fast and so is the thinking behind it. A firm's e-commerce strategy should aim to help organizations establish stronger ties with customers and business partners. These strategies should also focus on helping organizations acquire and retain customers efficiently. An electronic market not only offers a cheaper, more cost effective way to transact business but also brings about a more efficient market clearing mechanism, because it is not constrained by geographical distance or time.

The beginning of the second millennium will almost certainly be remembered as a time of unprecedented change in the business world. In the space of a few years entire industries have been radically transformed. New technologies such as Internet, digital televisions, intelligent home appliances have all reached critical mass at the same time and are poised to revolutionize business. To begin it's useful to describe what is meant by electronic business and electronic commerce. It is defined as 'the conduct of business on the Internet, not only buying and selling but also servicing customers and making strategic alliances with business partners.'

At this stage of development of e-commerce, everything that constitute a market products, industrial structure, trade is in the process of being redefined. This raises the issues of developing new strategies to answer questions like, how will the new networks affect industries and the economy at large, how should firms compete in the new market places that are developing, how can firm integrate the network into existing business operations and how they should manage the new organizations. This makes business strategy specialists to understand the networks and their business implications.

One of the advantages of using an electronic channel is the efficiency gain. E-business can generate tremendous efficiencies through reduced transaction costs, faster through out and better information to all members of the chain. Traditional strategy development process is difficult to be followed in the case of e-businesses, as it has to contend with additional issues of virtual transactions, unstable market, highly interconnected firm and high uncertainty in the markets. The most striking features of competitive strategies in e-business is that often new entrants have been able with limited resources to undermine existing competitions in the industry through the use of new business models. Strategy is driven by what is valued by the customer without being constrained by existing industry rules. E-business strategy makers build on the powerful commonalities in the features that customers value. This ensures these companies to capture the core of the market, even if it means that they lose some of the customers.

Apart from the instability of the market, one of the greatest challenges for e-business strategies is the sheer speed of change. Two processes are critical in time pacing. The first one is managing transitions or the shifts from one activity to the next. The second is managing rhythm, or the pace at which organizations change. Another

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area where e-strategists should concentrate is the ability to connect individuals, groups and organizations worldwide. Complementary product providers and allies play a significant role in determining success in the industry.

Uncertainty is another characteristic which the e-business strategies maker has to cop up with. A firm's posture in state of uncertainty defines the intent of a strategy relative to the current and future state of an industry. Strategies are aimed at creating new opportunities in a market, either by shaking up relatively stable industries or by trying to control the direction of the market in industries with higher level of uncertainty. Many e-commerce firms adopt the strategic posture of reserving the right to play, which involves making incremental investments now that will put a company in a position of advantage in the future. This allows the company to wait until the environment becomes less uncertain before formulating a strategy.

As e-business technologies, coupled with continued advances in voice recognition and artificial intelligence, become more commonplace, even more radical changes in the use of information are expected. Just as there has been a paradigm shift in e-business strategy, this requires a shift from information management to knowledge management. This will require systems that move beyond simply capturing past experiences to using that information creatively. Another strategy that can be adopted to cop with the speed of change and uncertainty of e-business is to establish a separate e-business unit. Speed and flexibility are required to compete successfully in e-business, something that is difficult to achieve in large organizations. The strategies of dot.com business are best seen as a tradeoff between operational decisions and financial decisions.

We are on the verge of a revolution that is just as profound as the change in the economy that came with the industrial revolution named 'E-revolution'. So the e-strategies should be formulated such that it allows people to rise above the barriers of time and distance and take advantage of global markets and business opportunities.

SUMMARY

- This unit helped the reader to know the importance of one of the inputs of production system, namely, the material resource.
- The functions of materials management is dealt.
- Types of computer controlled material handling devices and their applications are discussed.
- The operation of Just in Time (JIT) system and the prerequisites to implement JIT in an organization are discussed.
- The deterministic inventory models and probabilistic inventory model and when do you adopt which model is elaborated.
- The working of MRP – I and MRP – II is illustrated with examples.
- Introduction of ERP, e-business and e-operation strategies are outlined.

Review Question:

What is e-business and e-commerce?

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UNIT III
PLANNING AND FORECASTING

UNIT - 3

NOTES

PLANNING AND FORECASTING

3.1 INTRODUCTION

In this unit the three levels of management are discussed. Product design and development activities are also discussed. The enablers of product design and development namely Expert system, Computer Aided Design (CAD) are also elaborated. Forecasting activity is dealt to provide the input for the capacity planning and aggregate planning activities. Capacity planning overview is done with the explanations of aggregate planning.

3.1.1 Learning Objectives

1. You should understand the three levels of the management and their characteristics.
2. Different forecasting methods and forecasting evaluation tools are to be understood.
3. To understand the capacity planning and the strategies for aggregate planning and then different methods of aggregate planning.
4. To comprehend the new product development process and the utility of computer aided design and the expert system in the new product development process.

3.1.2 Levels of Management

Generally, business activities can be classified into strategic, tactical and operational level activities. All the three levels are involved in all the subsystems, namely, production, finance, personnel and marketing. The characteristics of the decisions to be taken in all the three levels are shown in the table 3.1.2

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Table 3.1.2 - Characteristics of decision making at Strategic, Tactical and Operational Levels of Management

Characteristics	Level of Management		
	Strategic	Tactical	Operational
Time frame to which decisions apply	"future" – Extremely long time	"Current" – Year, quarter, or month	"Instant" – day to day, or real-time
Persons primarily involved	Executive management and staff	Middle management	First line manage ment
Focus of decision	On one aspect of the organization/environment relationship at a time	On organization only, either in its entirely or a major portion of it	On small part of the organization
Complexity of decisions	Numerous variables, most of which cannot be quantified	Moderate number of variables; most of which can be quantified	Small number of variables, all of which can be quantified
Degree of structure in decision-making process	Occurs at irregular intervals, based almost exclusively on judgment; each problem differs.	Rhythmic; specifically prescribed procedures; repetitive problems	Rhythmic; specifi cally prescribed procedures; repetitive problems
Nature of information	External; predictive; qualitative; not particularly accurate precise	Internal; Historical or real-time; often non-financial; precise	Internal; historical or real-time; often non-financial;
Use of information	Prediction	Action	Action

You can see how the type of activities to be carried out in the strategic, tactical and operational levels of production system is shown below for your clarity.

Strategic level decisions in the production system are :

- Plant location decision
- New product introduction
- Technology Selection
- Supply chain network strategy

Tactical level decisions in the production system are :

- Markets to be supplied
- Aggregate planning
  - overtime estimation
  - inventory decision
  - subcontracting decision
  - hiring and firing decision

Operational level decisions in the production system are :

- deciding about the individual customer order
- allocation of inventory or production to individuals order
- deciding a date that an order is to be filled
- allocated can order to a particular shipping mode
- set delivery schedule of trucks

Review Questions :

1. What are the three levels of management?
   Give an example in each level of the management

3.2 FORECASTING

Forecasting activity is an important activity in the business. This is considered to be an important input for many activities in the organization. Forecasting is of two types, namely, long ranges forecasting and short range. The Long range forecast goes as input for long range decision making like technology selection, capacity planning. From the long range forecasts, the medium term forecasts are derived and used as input for the activity like aggregate planning. From the medium term forecasts the short range forecasts are outlined and go as input for activity like scheduling. Selection and usage of forecasting method differs according to whether the company needs forecast to the existing product or for a new product. When you forecast for the existing product, the past demand data is taken into consideration, the pattern for the demand is analyzed, then appropriate forecasting technique is chosen to predict the future. From the predicted demand the manager adds his own intuitions and experience based on the situation to change the estimated demand to suit the real life situation.

In the case of new product, since there is no past data available, the organization depends upon the qualitative methods of forecasting. Experts, customers, sales persons opinions are solicited.

3.2.1 Importance of forecasting

Forecasting activity plays major role in activities like budget preparation, cash flow preparation, balance sheet and income statement. In marketing it does play a role in product life, pricing and promotional decisions. In production it provides information in capacity planning, aggregate planning and scheduling activities.

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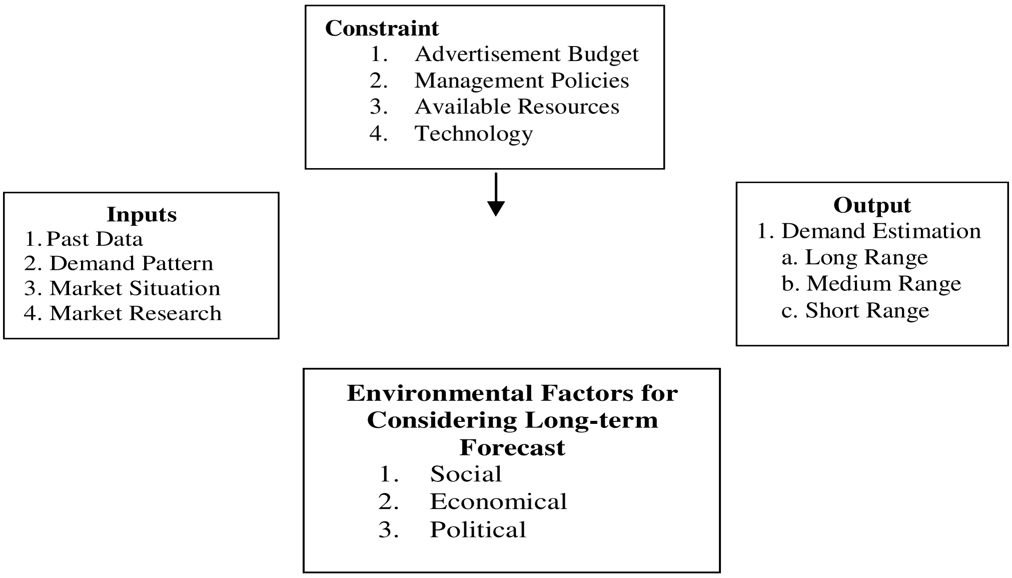
3.2.2 Forecasting model

Figure 3.1 - Forecasting model



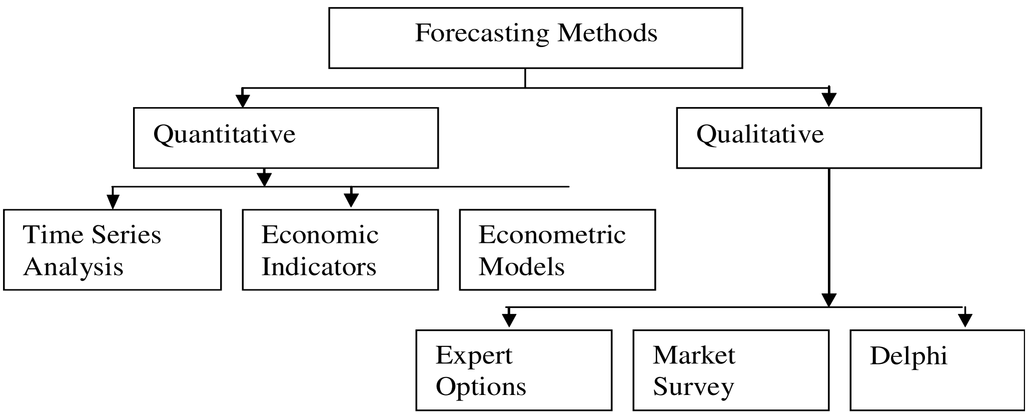
Before selecting any forecasting methods, you should see that whether you require forecasting for long range; then whole frame work given in the model is useful that is in addition to market and internal analysis you need to consider the environmental factors like social, economic and political factors for the long term forecasting.

3.2.3 Forecasting methods

In this material the forecasting methods are classified into quantitative and qualitative type. The past data and demand pattern play key role in selecting the best quantitative method and providing good forecasting results. Quantitative methods are very much used for forecasting the existing products. Qualitative method used for the new product forecast.

The classification of different methods is shown below figure 3.1

Figure 3.2 - Classification of forecasting method



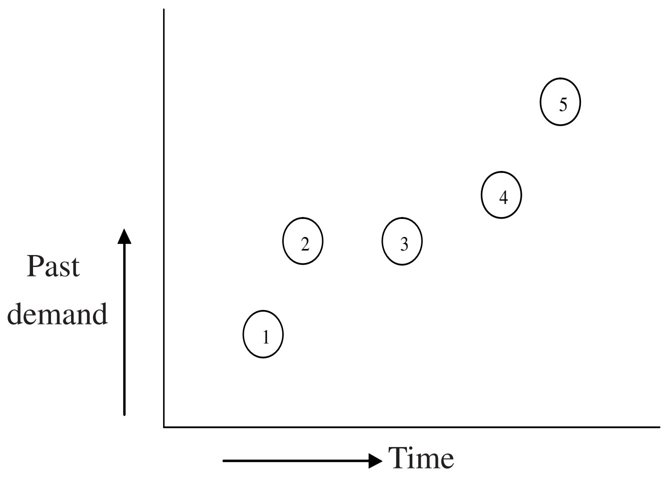
3.2.3.1 Quantitative methods:

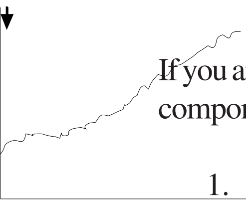
The method is called quantitative methods because forecasting is done based on the data.

Time series analysis:

In this method, the past data is analyzed against time scale.

Figure 3.3 - Time series analysis





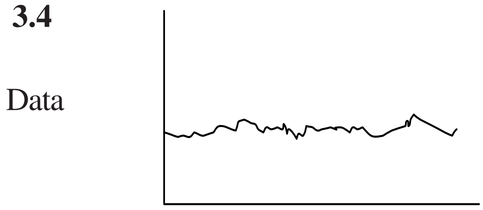
If you analyze the demand pattern against a time scale, usually it consists of the following components.

1. Level
2. Trend
3. Seasonal
4. Cyclic
5. Random

Before selecting a particular forecasting, the past data is plotted against their respective year or month or week the pattern analyzed in terms of what component the pattern posses, then the appropriate forecasting technique is chosen.

The combination of components is shown in figure3.4.

Figure 3.4



(Level + Random) **(Level+ Trend+ Random)**

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(Level+Seasonal+Random) **(Level+Trend+Seasonal+Random)**

Cycle component usually considered for the long term forecasting. The cycle means business cycle or economy cycle. The different phases of this cycle are growth, maturity and depression. Usually each phase may prevail for at least more than three years.

3.2.3.1.1 Time Series Analysis

For after analyzing the pattern of data, you can choose relevant method for forecasting. In this material important and complicated time series analysis methods are discussed.

Moving Average

The moving average technique generates the next period's forecast by averaging the actual demand for the last 'n' time periods.

$$\hat{Y}_t = \frac{Y_{t-1} + Y_{t-2} + ...Y_{t-n}}{n} = \frac{\sum_{i=1}^{n} Y_{t-1}}{n}$$

Where = forecast for period 't '

= actual demand in period 't '

n = Number of periods included in each average

Moving average problem – 1

From the data below, determine the forecast for period 7 using two month moving average technique.

Table 3.2

Month	1	2	3	4	5	6
Demand	20	30	40	30	50	58

Solution:

Moving average period (n) = 2

Forecast for period 7 would be $= \frac{50+58}{2} = 54$

NOTES

Moving Average – Problem 2

From the data below, determine MAD for the following forecasting techniques: (a) last period demand, (b) arithmetic average, and (c) three month moving average. What is the forecast for period 13?

Table 3.3

Period	Demand	Period	Demand
1.	93	7.	100
2.	105	8.	101
3.	114	9.	81
4.	111	10.	118
5.	106	11.	103
6.	116	12.	114

		Last Period Demand		Arithmetic Average		Three Month Moving Average	
Month	Demand demand	Forecast deviation	Absolute demand	Forecast deviation	Absolute demand	Forecast deviation	Absolute
1	93	-	-	105.16	12.16	-	-
2	105	93	12	105.16	0.16	-	-
3	114	105	9	105.16	8.84	-	-
4	111	114	3	105.16	5.84	104.00	7.00
5	106	111	5	105.16	0.84	110.00	4.00
6	116	106	10	105.16	10.84	110.33	5.67
7	100	116	16	105.16	5.16	111.00	11.00
8	101	100	1	105.16	4.16	107.33	6.33
9	81	101	20	105.16	24.16	105.67	24.67
10	118	81	37	105.16	12.84	94.00	24.00
11	103	118	15	105.16	2.16	100.00	3.00
12	114	103	11	105.16	8.84	111.67	13.30
13	114	Total 139	105.16	Total 96.00	111.67		Total 98.97

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$$= \frac{139}{11} = 12.63$$

$$MAD = \sum_{i=1}^{n} \frac{\left|Y_i - \hat{Y}_i\right|}{n} = \frac{96}{12} = 8$$

$$MAD = \sum_{i=1}^{n} \frac{i\left|Y_i - \hat{Y}\right|}{n} = \frac{98.97}{9} = 10.99$$

Forecast for period 13 using last period demand = 114

Forecast for period 13 using arithmetic average = 105.16

Forecast for period 13 using three month moving average = 111.67

Exponentially weighted moving average

In the simple moving average technique, recent 'n' data have to be taken while calculating the forecast. 'n' represents, 'n' month moving average', exponentially weighted moving average gives more weightage to the recent data and less weightage to the old data moreover if you apply this technique to forecast the future, there is no need to store recent 'n' data as you did in the moving average method. Because all the data will be in one single value that is the previous forecast value.

Simple exponentially moving weightage average model

Forecast for period t = α (Actual demand of period t-1) + (1-α) (forecasted value of t-1)

This model is applicable only when the past data follows a horizontal pattern with error component.

Figure 3.5 - Simple exponentially moving weightage average model

Where 'α' is the exponential smoothening constant, α varies between 0 to 1.let us analyze why this method is called exponential weighted moving average.

NOTES

Forecast for period t

= (actual demand for period t-1) + (1- α) (forecasted value for t-1)

$\hat{X}_t$ = forecast for the level component for period t

$$\hat{X}_t = Y_{t-1}\alpha + (1-\alpha)\left[Y_{t-2}\alpha + (1-\alpha)\hat{X}_{t-2}\right]$$

$$= \alpha Y_{t-1} + \alpha(1-\alpha)Y_{t-2} + (1-\alpha)^2\hat{X}_{t-2}$$

$$= \alpha Y_{t-1} + \alpha(1-\alpha)Y_{t-2} + (1-\alpha)^2\left[Y_{t-3}\alpha + (1-\alpha)\hat{X}_{t-3}\right]$$

From the above expressions, you can easily understand that the past data gets less weightage than the recent data as follows:

DATA	WEIGHTAGE	FOR α =0.4
Y_t-1	α	0.4
Y_t-2	α (1-α)	0.24
Y_t-3	α (1-α)^2	0.144

$\hat{X}_t = Y_{t-1}\alpha + (1-\alpha)\hat{X}_{t-1}$

If you plot the weightage against the time data, it follows exponential pattern, so the method is called as exponentially weighted moving average.

Exponentially weighted moving average with trend correction (Level + Trend)

When you analyze the past data and if you have a feeling that the past data contains both the level(X) and trend component (T), then the model is used for adjusting trend and level component is

= α Y_{t-1} + (1 - α) ($_{-1}$ + T_{t-1})

Tt = β ( ) + (1 - β) T_{t-1}

T_t = Trend adjustment for period 't'.

β is a smoothing constant for trend. This varies between 0 and 1.

Now the forecast for period t

+ T_t

If you want to forecast for 'n' period from the period 't' where in the forecast value available are $\hat{X}_t$ and T_t, then the formula to be used

$\hat{Y}_{t+n}$ = $\hat{X}_t$ + (n + 1) T_t

Exponentially weighted moving average Problem - 3

Using exponential smoothing and the data in the previous problem, forecast monthly demand if α = 0.2 and = 0.4. Assume that the actual demand in the first

NOTES

month is the same as the forecasted demand and the initial level and the initial trend for month 1 both are 10. From these results forecast the demand for period 8.

Table 3.5

Month	Y_t Demand	Forecast Level	Tt Trend	Forecast
1	20	10	10	20
2	30	20	10	30
3	40	30	10	40
4	30	40	10	50
5	50	46	8.4	54.4
6	58	53.52	8.048	61.568
7	54	60.85	7.752	68.602
8		65.68	6.583	72.263

α = 0.2, = 0.4

Table 3.6

Month	Y_t Demand	Forecast	Tt Trend Level	$\hat{Y}_t$ Forecast
1	20	10	10	20
2	30			
3	40			
4	30			
5	50			
6	58			
7	54			
8				

$\hat{X}_t = \alpha\ Y_{t-1} + (1 - \alpha)(\quad_{-1} + T_{t-1})$

$Tt = \beta\ (\quad - \hat{X}_{t-1}) + (1 - \beta)\ T_{t-1}$

T_t = Trend adjustment for period 't'.

$= \hat{X}_t + T_t$

Forecast demand level for the 2nd month is obtained in the following manner

$\hat{X}_2 = 0.2 * (20) + 0.8 * (10 + 10)$

$= 4 + 16$

$= 20$

NOTES

Trend for the 2nd month is obtained in the following manner:

$T_2 = 0.4 * (20 - 10) + 0.6 * (10)$

$= 4 + 6$

$= 10$

Forecast for month 2 is

$Y_2 = \hat{X}_2 + T_2$

$= 20 + 10$

$= 30$

Forecast demand level for the 3rd month is obtained in the following manner:

$\hat{X}_3 = 0.2 * (30) + 0.8 * (20 + 10)$

$= 6 + 24$

$= 30$

Trend for the 3rd month is obtained in the following manner:

$T_3 = 0.4 * (30 - 20) + 0.6 * (10)$

$= 4 + 6$

$= 10$

Forecast for month 3 is

$\hat{Y}_3 = \hat{X}_3 + T_3$

$= 30 + 10$

$= 40$

Forecast demand level for the 4th month is obtained in the following manner:

$\hat{X}_4 = 0.2 * (40) + 0.8 * (30 + 10)$

$= 8 + 32$

$= 40$

Trend for the 4th month is obtained in the following manner:

$T_4 = 0.4 * (40 - 30) + 0.6 * (10)$

$= 4 + 6$

$= 10$

Forecast for month 4 is

$\hat{Y}_4 = \hat{X}_4 + T_4$

$= 40 + 10$

$= 50$

Forecast demand level for the 5th month is obtained in the following manner:

$\hat{X}_5 = 0.2 * (30) + 0.8 * (40 + 10)$

$= 6 + 40$

$= 46$

NOTES

Trend for the 5th month is obtained in the following manner:

$T_5 = 0.4 * (46 - 40) + 0.6 * (10)$
$= 2.4 + 6$
$= 8.4$

Forecast for month 5 is

$\hat{Y}_5 = \hat{X}_5 + T_5$
$= 46 + 8.4$
$= 54.4$

Forecast demand level for the 6th month is obtained in the following manner:

$\hat{X}_6 = 0.2 * (50) + 0.8 * (46 + 8.4)$
$= 10 + 43.52$
$= 53.52$

Trend for the 6th month is obtained in the following manner:

$T_6 = 0.4 * (53.52 - 46) + 0.6 * (8.4)$
$= 3.008 + 5.04$
$= 8.048$

Forecast for month 6 is

$\hat{Y}_6 = \hat{X}_6 + T_6$
$= 53.52 + 8.048$
$= 61.568$

Forecast demand level for the 7th month is obtained in the following manner:

$\hat{X}_7 = 0.2 * (58) + 0.8 * (53.52 + 8.048)$
$= 11.6 + 49.25$
$= 60.85$

Trend for the 7th month is obtained in the following manner:

$T_7 = 0.4 * (60.85 - 53.52) + 0.6 * (8.048)$
$= 2.932 + 4.82$
$= 7.752$

Forecast for month 7 is

$\hat{Y}_7 = \hat{X}_7 + T_7$
$= 60.85 + 7.752$
$= 68.602$

Forecast demand level for the 8th month is obtained in the following manner:

$\hat{X}_8 = 0.2 * (54) + 0.8 * (60.85 + 7.752)$
$= 10.8 + 54.88$
$= 65.68$

NOTES

Trend for the 8th month is obtained in the following manner:

$T_8 = 0.4 * (65.68 - 60.85) + 0.6 * (7.752)$

$= 1.932 + 4.651$

$= 6.583$

Forecast for month 8 is

$\hat{Y}_8 = \hat{X}_8 + T_8$

$= 65.68 + 6.583$

$= 72.263$

Exponentially weighted moving average with seasonal correction (Level + Seasonal)

When you analyze the past data, if you identify that the past data contains level and seasonal pattern. The seasonal pattern means that you can find the similarity in the demand pattern with respect to each period. This similarity occurs within a year.

(e.g.).Demand of Air-conditioning equipment, Heating equipment, Ice Cream, Etc...

The last year demand in the month of January may have the similarity with the demand of January of this year. If you have monthly data, then the seasonal period = 12, if you have quarterly data, then the seasonal period = 4.

When there is no trend, the model used for forecasting

$\hat{Y}_t = \hat{X}_t I_t$

Where

$\hat{Y}_t$ = forecast for the period 't'

$\hat{X}_t$ = level forecast for the period 't'

I_t = seasonal index for the period 't'

The seasonal index also are updated by the following model:

$I_{t+m} = \gamma \quad + (1 - \gamma) I_t$

Where is the seasonal smoothing constant, it varies between 0 and 1.

If you want to forecast for the 'n' period, where in you have then the forecast for the period 'n' after t

$\hat{Y}_{t+n} = \hat{X}_t I_{t+n}$

Exponentially weighted moving average Problem -4

Quarterly data for 12 periods is given below:

NOTES

Table 3.7

Quarter	Demand	Quarter	Demand
1.	497	7.	821
2.	454	8.	1017
3.	624	9.	709
4.	764	10.	715
5.	631	11.	1794
6.	624	12.	1242

Using the data from the first eight quarters, compute the quarterly seasonal indices.

Solutions -

Table 3.8

Period	Demand	Average of same quarter of each year	Seasonal Index
1	497	564	0.83
2	454	539	0.793
3	624	722.5	1.064
4	764	890.5	1.311
5	631	564	0.83
6	624	539	0.793
7	821	722.5	1.064
8	1017	890.5	1.311
Total	5432		7.996

Overall quarterly average $= \frac{5432}{8} = 679$

$$\text{Seasonal Index} = \frac{\text{Average of same quarter of each year}}{\text{Overall quarterly average}}$$

Seasonal Index for Quarter 1 $= \frac{564}{679} = 0.83$

Seasonal Index for Quarter 2 $= \frac{539}{679} = 0.793$