Operations Management

Course Teacher

Dr. Sricharan

Mechanical Engineering Department

S. R. K. R. Engineering College, Bhimavaram

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UNIT 1

Operations Management

- Introduction and Definition
- Operations/Production system model
- Examples of various Operations/Production systems
- Factors affecting OM
- Typical operations under OM.

Forecasting

- Importance of forecasting in OM
- Different types of forecasting
- Methods of Forecasting: qualitative and quantitative

UNIT 1 – OPERATIONS MANAGEMENT & FORECASTING

Introduction to Operations Management (OM)

In the current era of the global businesses driven by Information and Communication Technologies, Integrated Enterprise Software Systems, and Flexible Automation Systems, the way the organizations **manage their operations**, the **speed** at which they make **decisions**, and the improvement in the **quality of products and services** is mind-boggling.

This is possible because of advances in computer technologies and software applications which made **more information** to be available and **easily accessible**. For example, popular Enterprise Resource Planning (ERP) software such as SAP, PeopleSoft, and Oracle allows operations managers to obtain **near-real-time information** about inventory levels, customer orders, current workloads, orders to vendors, and so on. Also, the advances in communication technologies allowed firms to more **easily manage international** operations and to work on projects in globally dispersed teams.

Adding to all this the **e-business** is a new brand outlet from which all firms can market and sell their goods and services. With the enormous amount of information that is available to the consumers now on the internet, the **consumer expectations** for quick response and high quality have escalated. This indeed is a very **exiting time for the field of OM.**

Whether you choose a **career in OM or some other business** field such as accounting, finance, human resources, information systems, or marketing, what you study in this course on OM will be important to you because you will interact with others in your organizations operations areas. By better understand various **operations** in OM, and the **challenges and issues** facing operations managers, you will be **more effective** as you **cooperate and work together** to achieve what is the best interest of your organization.

Adding value by improving OM

Better management of company's operations can add substantial value to the company by improving its competitiveness and long term profitability. Consider the following examples of important decisions at a few companies:

1. Intel needs to construct a new multibillion-dollar fabrication plant to produce its next generation of computer chips. Where should it build the factory? – ***Plant location problem***.
2. An airlines needs to allocate the necessary resources to meet all of its customer demand for air travel next month. How should it assign different sized aircraft to flight routes, pilots to aircraft, and flight attendants to flights? – ***Allocation problem***.
3. Hewlett-Packard needs to increase output for one model of printer ink cartridges on a production line that is already running at full capacity. What is the most cost-effective way to redesign the production line to increase the output? – ***Production line design problem.***

4. The manager of a call centre wants to better utilize the call answering staff and avoid long waiting's for callers by improving forecast accuracy. What method should be used to forecast the number of calls received during each work shift? – ***Forecasting problem***.

These are some of the samples of types of **problems faced by operations managers**. **Poor operations decisions** can hurt a company's competitive position and increase its costs. **Good operations decisions** can improve the value of the company by increasing profitability and growth. Understanding the **fundamental concepts** of operations management and being able to use a variety of **common decision making tools and problem solving approaches** is **key to making better** operations decisions. **Hence,** OM is an important discipline in the struggle to remain competitive in an ever-changing global market place.

Note: *The information provided until now can provide the possible answers for the questions like, "Why do we study OM?", "Examine the role and importance of POM today's scenario", "Explain about need of production and operational management", "Write short notes on the significance of operation management", "What do you understand by OM?", "Discuss the nature of the OM", etc.*

Of the many functions in business, there are **three primary functions**: operations, marketing, and finance/accounting. **Our course** is about operations management.

An **earlier name** for this activity was production and operations management **(POM),** which has now been shortened to operations management (OM). The management **approaches and tools** addressed in this course of OM were originally applied **primarily in manufacturing companies**, where the focus was on production management. These approaches and tools later were also applied to **service organizations**. But most manufacturers have service activities as well as production activities, so the study of this discipline was then referred to as POM. Some organizations have only a production manager, some have only an operations manager, and some have both a production manager and an operations manager. Today this discipline is generally referred to **simply as OM**, but includes **both the** management of **production activities** and the management of **other operations**.

Note: *The above information can be included if the question is like, "What is production and operational management? Make an overview about POM/OM". Also you can add the definition of OM (in the upcoming slides) to answer this question.*

Comparison of manufacturing and services

The differences between manufactured goods and services are as follows:

- ***Simultaneous production and consumption.*** High contact services (e.g. health care, petrol/gas stations) must be produced in the **presence of the customer**, since they are **consumed as produced**. As a result, services cannot be produced in one location and **transported** to another, like goods. Service operations are therefore **highly dispersed** geographically close to the customers. Only low-contact services produced in the "backroom" (e.g., check clearing) can be provided away from the customer.
- ***Perishable.*** Since services are perishable, they **cannot be stored** for later use. In manufacturing companies, **inventory** can be used to buffer supply and demand. Since buffering is not possible in services, highly variable demand must be met by **highly flexible operations** or demand modified to meet supply. Also, **Revenue management** is important for service operations, since empty seats on an airplane are lost revenue when the plane departs and **cannot be stored for future use**.
- ***Ownership.*** In manufacturing, ownership is transferred to the customer. Ownership is not transferred for service. As a result, services **cannot be owned or resold**.

- ***Tangibility.*** A service is intangible making it **difficult for a customer to evaluate** the service in advance. In the case of a manufactured good, customers can see it and evaluate it. Assurance of quality service is often done by licensing, government regulation, and branding to assure customers they will receive a quality service.

  These four comparisons indicate how management of service operations are **quite different** from manufacturing regarding such issues as highly variable capacity requirements, hard to quantify quality assurance, dispersed location of facilities, and presence of the customer during delivery of the service.

  While there are differences there are also many **similarities**. For example, quality management approaches used in manufacturing such as the **Baldrige Award, and Six Sigma** have been widely applied to services. Likewise, **Lean service** principles and practices have also been applied in service operations. The important difference being the ***customer is in the system while the service is being provided and needs to be considered*** when applying these practices.

  One important difference is **service recovery**. When an error occurs in service delivery, the recovery must be delivered **on the spot** by the service provider. If a waiter in a restaurant spills soup on the customer's lap, then the recovery could include a free meal and a promise of free dry cleaning.

Note: *This could be the answer for the questions like, "Distinguish between manufacturing and service organization" and "Differentiate between characteristics of goods and services".*

Definition of OM

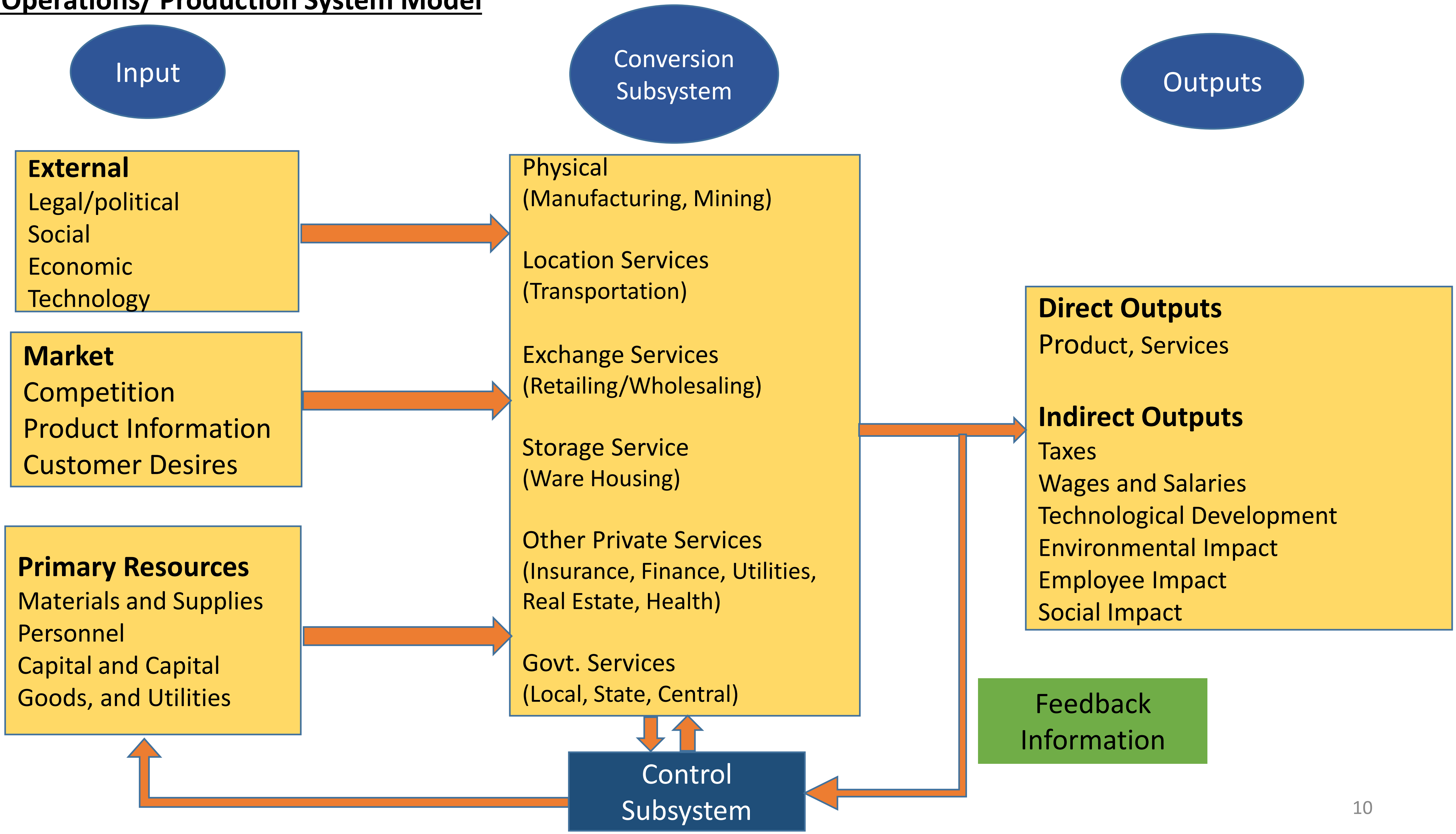
“OM is the management of the organization’s productive resources or its production system, which converts inputs into the organization’s products and services.”

A *production/operations system* takes inputs – raw materials, personnel, machines, buildings, technology, cash, information, and other resources – and converts/transforms them into outputs – products and services. This ***conversion/transformation process*** is the **heart** of what is called operations or production and is the predominant activity of a production/operation’s system. Because managers in POM/OM, whom we shall simply call **operations managers,** their primary concern is with the activities of the **conversion process** or production.

A system view of operations

If we want to study firm’s operations as a system, an operations or production system receives **inputs** in the form of materials, personnel, capital, utilities, and information. These inputs are changed in a **conversion subsystem** into the desired products or services, which are called **outputs**. The output is monitored in the **control subsystem** to determine if it is acceptable in terms of quantity, cost, and quality. If it is not acceptable, the control subsystem ensures system performance by providing **feedback** so that corrective action can be taken by managers.

An Operations/ Production System Model



Inputs are classified into three general categories – external, market, and primary resources.

External inputs generally are informational in character and tend to provide operations manager with knowledge about the conditions outside the operations/product system.

i. *Legal or political inputs* may establish **constraints within which** the system must operate.

ii. *Social and economic inputs* allow operations managers to sense **trends that may affect** the system.

iii. *Technological inputs* may come from trade journals, government bulletins, trade association news letters, suppliers and other sources. This information provides managers with knowledge of important **breakthroughs in technology that affect** machinery, tools, or processes.

Like external inputs, **market inputs** tend to be informational in character. Information concerning competition, product design, customer desires, and other aspects of market is essential if the system is to respond to the **needs of the market**.

Inputs that **directly support** the **production and delivery of goods and services** are referred to as **primary resources.** These are materials and supplies, personnel, capital and capital goods, and utilities (water, gas, coal, oil, electricity).

The **direct outputs** of operations systems are usually of two forms, tangible or intangible. An enormous array of **tangible goods** or products is produces each day – automobiles, laptops, hair dryers, calculators, toothpicks, clothes, cakes, printers, soaps, etc. Similarly, **services – the intangible outputs** that pour from operations system - seem inexhaustible: education, hospitals, haircuts, banking, insurance, lodging, transportation, government agencies, etc.

Interestingly, we often overlook **indirect outputs** of production system. Taxes, waste and pollution, technological advances, wages and salaries, and community outreach activities are some of the examples of indirect outputs. Although they do not receive the same attention as the products and services outputs that generate the revenues which perpetuate the system, these indirect outputs are a cause of both **concern and pride**.

The core of the operations/production system is its **conversion subsystem**, wherein workers, materials, and machines are used to convert inputs into products or services. The process of conversion is at the **heart of OM** and is present in **some form in all organizations**. Wherein this conversion process is carried out and what we call the department or function where it is located **vary greatly** among organizations. In manufacturing firms, the department or function where this conversion process is carried out is called as the manufacturing function/department and in other firms like retailing, trucking, etc. it is called as operations function.

Understanding the operations/production system concepts (inputs, conversion subsystems, and outputs) leads **to improved management** of these systems and **better decision making**. The decision making could be ***strategic decisions*** (planning of products, processes, and facilities which have long-term significance on the organization), ***operating decisions*** (planning production to meet the demand and make profits for the company which have medium-term significance on the organization), and ***control decisions*** (planning and controlling operations like day to day activities of the workers, quality of products and services, production and overhead costs, and maintenance of equipment which have short-term significance on the organization).

Note: *The information in this slide could be the part of the answer for the question, "What are the benefits of OM/POM?", "What is the competitive advantage through operations".*

Note: *The possible questions on Operations/Production system are:*

- *Define operations/production system. How does the concept of production system help in the understanding of OM?*
- *Explain the transformation process model of Operations Management.*
- *What are the inputs to operations/production systems? How can they be classified?*
- *Define conversion subsystems. How can they be classified? (or) Make a note of different production/operations systems. (or) How are the different production/operations systems classified?*
- *Describe the primary inputs, outputs, and conversion subsystems of the following organizations: a. department store, b. automobile factory, c. software industry, d. medical clinic, e. fire station, f. chemical plant, and g. engineering college.*

Some Typical Production or Operations Systems

Production System	Primary Inputs	Conversion Subsystem	Outputs
Department store	Buildings, displays, shopping carts, computers, stock goods, personnel, supplies, utilities, customers	Attracts customers, store goods, sells products (Exchange service)	Marketed goods
Accounting firm	Supplies, personnel, information, computers, buildings, office furniture, machines, utilities	Attracts customers, compiles data, supplies management information, computes taxes (Private service)	Management information, tax services, and audited financial statements
Automobile factory	Purchased parts, raw materials, supplies, paints, tools, equipment, personnel, buildings, and utilities	Transforms raw materials into finished automobiles through fabrication and assembly operations (Physical)	Automobiles
Automobile body shop	Damaged autos, paints, supplies, machines, tools, buildings, personnel, utilities	Transforms damaged auto bodies into fascimiles of the originals (private service)	Repaired automobile bodies

Contd…

Production System	Primary Inputs	Conversion Subsystem	Outputs
Trucking firm	Trucks, personnel, buildings, fuel, goods to be shipped, packaging, supplies, truck parts, utilities	Packages and transports goods from sources to destinations (Locational service)	Delivered goods
College or University	Students, books, supplies, personnel, buildings, utilities	Transmits information and develops skill and knowledge (private/public service)	Educated persons
Food factory	Grains, pulses, water, personnel, buildings, utilities, tools, machines, paper bags, cans	Converts raw materials into finished goods (Physical)	Food products

Typical operations under OM

To get an integrated perspective on OM the operations under OM, which are all dealt by the operations manager can be broadly categorized into three categories: *Planning, Organizing, and Controlling*, all revolving around the heart of the OM, i.e. **Conversion process.**

Planning the conversion system: The operations manager defines the objectives for the operations system of the organization, and the policies, programs, and procedures for achieving the objectives. It also involves product planning, facilities designing, etc. *Planning* is further divided into two major parts: ***planning* and *scheduling*** the conversion system. Planning the conversion system revolves around its **design**; scheduling focuses on **operating** it once it exists.

Controlling the conversion system: To ensure that all the plans are accomplished, the operations manager must exercise control by measuring actual outputs and **comparing** them to planned outputs. Controlling **costs, quality, and schedules** is at the very heart of OM. It also deals with inventory control, materials management, and quality management.

Organizing the conversion system: Operations managers establish a **structure** of roles, authorities and responsibilities and set the flow of information to achieve the goals of operations system. This organizing for conversion process includes job design, production/operations **standards, work measurement**, and project management.

Note: *The possible question from this is Explain how operations are classified".*

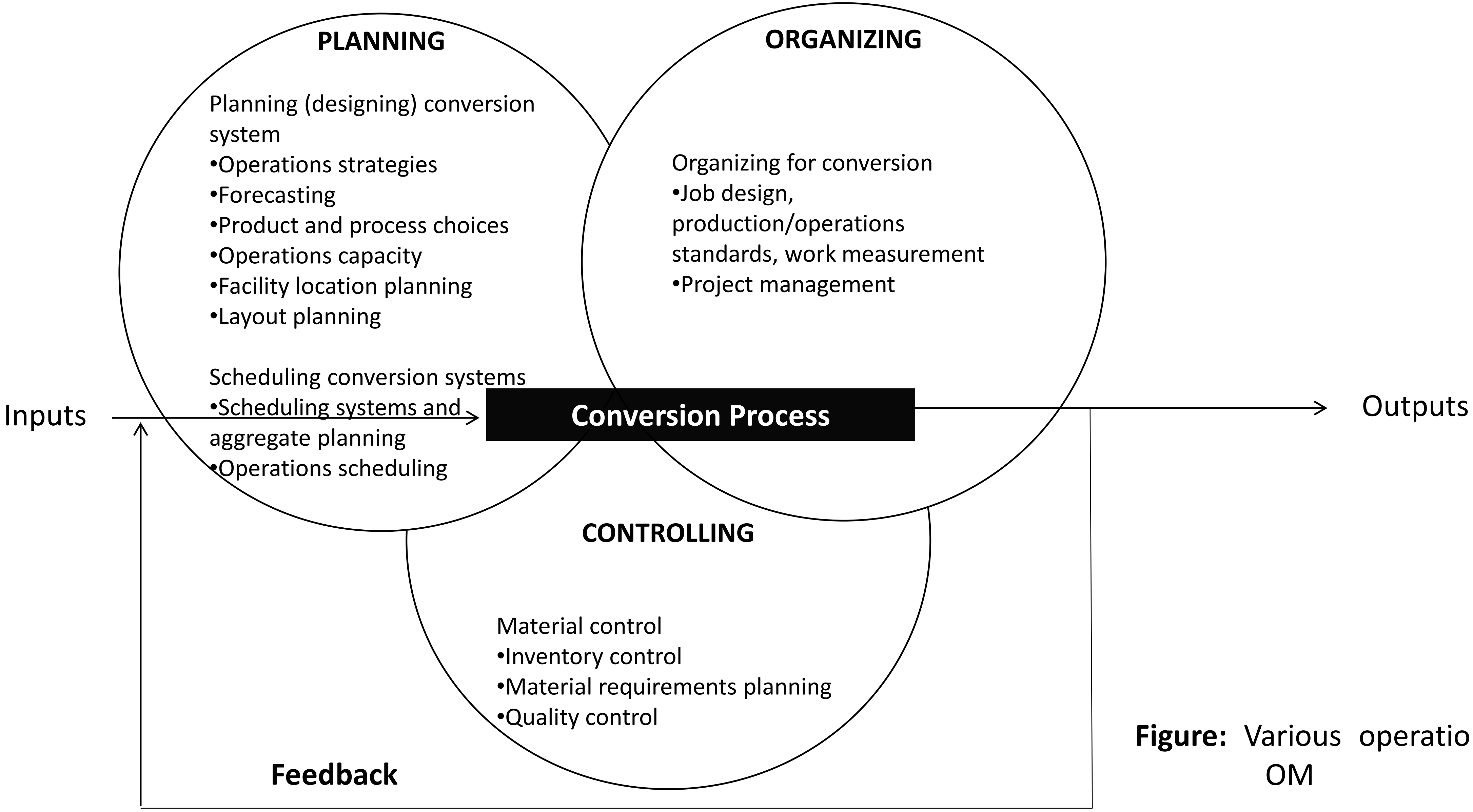


Figure: Various operations in OM

Factors affecting OM

Of the factors affecting OM today, six have had a major impact:

1. Reality of global competition
2. Quality, customer service, and cost challenges
3. Rapid expansion of advanced technologies
4. Continued growth of the service sector
5. Scarcity of operations resources
6. Social responsibility issues

A key impact of these factors on operations managers is that a country's borders no longer provide protection from foreign imports, i.e. **global competition** has become intense and is ever increasing. To succeed in this global competition, companies must make a commitment to **customer responsiveness and continuous improvement** toward the goal of quickly developing innovative products and services that have the best combination of exceptional quality, fast and on-time delivery, and low prices and costs. And this competition dictates that operations managers use more **sophisticated methods** made possible by rapidly expanding **advanced technologies**.

And as if the challenges of global competition were not enough, operations managers jobs are complicated by the need for more effective management of the **expanding service sector**; **scarcity** of capital, materials, and other resources for operations; and the need for operations managers to exercise more **social responsibility**. These factors do indeed create an interesting and challenging opportunity for operations managers to cope and succeed in this environments by developing long range game plans.

Note: *The possible question from this is "What are the most important factors affecting operations management today?".*

FORECASTING

What is a forecast?

Forecasts are **estimates** of the occurrence, timing, or magnitude of **future events**. They give operations managers a **rational basis** for planning and scheduling activities, even though actual demand is quite uncertain. Hence, the **first step** in planning is therefore forecasting, or estimating the future **demand** for products and services and the **resources necessary** to produce these outputs.

Why do firms forecast?

Accurate projections of future activity levels can **minimize short-term fluctuations in production** and helps **balance workloads**. This lessens hiring, firing, and overtime activities and helps maintain good labour relations. Good forecasts also help managers have appropriate levels of materials available when needed. By anticipating employment and material needs, the forecasts enable managers to make better use of facilities and give improved service to customers. Thus the ways firms benefit from forecasts could be summarised as follows:

- Improved employee relations
- Improved materials management
- Better use of capital and facilities
- Improved customer service

Costs of forecasting

Forecasting activities can be **costly**, so it is important to assess their **benefits versus their costs**. As the **forecasting activity increases**, data requirements increases, with the attendant costs of collection and analysis. Accordingly, the system for reporting and controlling must also be expanded. On the other hand, **reduced forecasting activity** may result in **unplanned** labour, materials, or capital costs, expediting costs, and ultimately **lost revenues**. The costs of not forecasting can be significant.

Types of forecasts

Forecasts are often classified according to time period/horizon. For example,

•Short-range – up to 1 year(typically 0 to 3 months)

•Medium-range – 1 to 3 years

•Long-range – 5 years or more

Operations managers need long-range forecasts to make **strategic decisions** about products, processes, and facilities. They also need short-range forecasts to assist them in making decisions about operations issues that span only the next few days or weeks. To state this more elaborately, let us look at the reasons summarised in **Table 1** for why the operations managers must develop forecasts. Also, the **table 2** cites some examples of things that are commonly forecasted in the given time horizons. For example, when long range forecasts estimate demand for entire product lines such as lawn products, medium-range forecasts group products into product families such as lawn movers, and short-range forecasts focus on specific products such as lawn mover model #345 (say).

Table 1: Some reasons why forecasting is essential in OM

1. **New Facility Planning:** It can take as long as five years to design and build a new factory or design and implement a new production process. Such strategic activities in OM requires long range forecasts of demand for existing and new products so that operations managers can have the necessary *lead time to build factories and install processes* to produce the products and services when needed.

2. **Production planning:** Demand for products and services **vary from month to month**. *Production and service rates* must be scaled up or down to meet these demands. It can take **several months to change the capacities of production processes**. Operations managers **need medium range forecasts** so that they can have the **lead time** necessary to provide the *production capacity* to produce these variable monthly demands.

3. **Workforce scheduling:** Demand for products and services **vary from week to week**. The *workforce* must be scaled up or down to meet these demands by using reassignment, overtime, layoffs, or hiring. Operations managers need short range forecasts so that they can have the lead time necessary to provide *workforce changes* to produce the weekly demands.

Table 2: Some examples of things that must be forecasted in OM

Forecast Horizon	Examples of things that must be forecasted
Long range	New product lines Old product lines Factory capacities Capital funds Facility locations
Medium range	Product groups Departmental capacities Workforce Purchased material Inventories
Short range	Specific products Labour-skill classes Machine capacities Cash Inventories

Methods of forecasting

Qualitative forecasting methods

These methods are usually based on **judgements** about the **causal factors** that underlie sales of particular products or services and on **opinions** about the relative **likelihood** of those causal factors being present in the future. These methods may involve several levels of sophistication, from scientifically conducted **opinion surveys to intuitive hunches** about future events. The following is the brief description about the various qualitative forecasting methods:

1. **Educated guess.** This is made when **one person** uses his or her best judgement, based on **experience and intuition**, to estimate a sales forecast. This approach is often used for **short-term** forecasts when the cost of forecast accuracy is low. For example, the **owner of a small departmental store** might use his experience and intuition to decide the quantity of a particular item to order for next week to meet demand. Since this type of forecasting occurs frequently, an educated guess is the **most common** approach to forecasting.

2. **Executive committee consensus.** Knowledgeable **executives from various departments within the organization** form a committee charged with the responsibility of developing a sales forecast. The committee may use many inputs from all parts of the organization and may have staff analysts provide analysis as needed. Such forecasts tend to be **compromised forecasts**, not reflecting the **extremes** that could be present had they been prepared by individuals.

3. **Delphi method.** This method is used to achieve **consensus within** a committee. In this method, executives **anonymously** answer a series of questions on successive rounds. **Each response** is fed back to **all participants** on **each round**, and the process is then **repeated**. As many as six rounds before consensus is reached on the forecast. This method can result in forecasts that **most participants** have **ultimately agreed to** in spite of their initial disagreement.

4. **Survey of sales force.** Estimates of future regional sales are obtained from **individual members of the sales force**. These estimates are combined to form an estimate of sales **for all regions**. Managers must then **transform this estimate into a sales forecast** to ensure realistic estimates. This is a popular forecasting method for companies that have a **good communication system in place** and that have **sales people who sell directly to customers**.
5. **Survey of customers.** Estimates of future sales are obtained directly from customers. Individual customers are surveyed to determine what quantities of the firms products they intend to purchase in each future time period. A sales forecast is determined by **combining individual customer's responses**. This method may be preferred by companies that have **relatively few customers**, such as **automobile industry suppliers and defence contractors**.
6. **Historical analogy.** This method ties the estimate of future sales of a product to knowledge of a **similar products sales**. Knowledge of one products sales during various stages of its product life cycle is applied to the estimate of sales for a similar product. This method may be particularly useful in forecasting sales of **new products.**
7. **Market research.** In market surveys, mail questionnaires, telephone interviews, or field interviews form the basis for testing hypotheses about real markets. In market tests, products marketed in **target regions or outlets** are statistically **extrapolated** to **total markets**. These methods are ordinarily preferred for **new products** or for **existing products to be introduced** into new market segments.

In summary, an **educated guess** is made when one person uses his or her intuition and experience to estimate a forecast. It is most often used when the cost of forecast inaccuracy is low. **Executive committee consensus** and the **Delphi method** describe procedures for assimilating information within a committee for the purpose of generating a sales forecast and are useful for either existing or new products or services. On the other hand, the **survey of sales force** and **survey of customers** describe methods that are primarily used for existing products or services. **Historical analogy** and **market surveys and tests** describe procedures that are useful for new products and services. The forecasting method that is appropriate, therefore, depends on **a product's life cycle stage**.

Quantitative forecasting models

These are **mathematical models based on historical data**. Such models **assume that past data are relevant** to the future. Although many more quantitative forecasting models exist, the following models provide a useful introduction to the forecasting in OM. All these models can be used with **time series**. A time series is a set of observed values measured over successive time periods, such as monthly sales for the last two years.

1. **Moving average.** A short-range time series type of forecasting model that forecasts sales for the next time period. In this model the **arithmetic average** of the actual sales for a specific number of most recent past time periods is the forecast for the next time period.
2. **Weighted moving average.** This model is like the moving average model described above except that instead of an arithmetic average of past sales, a **weighted average** of past sales is the forecast for the next time period. Typically, more weight would be placed on the most recent time periods.

3. **Exponential smoothing.** This is also a **short-range** time series forecasting model that forecasts sales for next time period. In this method the forecasted sales for the **last period** is modified by information about the **forecast error** of the last period. *This modification* of the last periods forecast is the forecast for the next time period.

4. **Exponential smoothing with trend.** The exponential smoothing model described above but modified to accommodate data with a **trend pattern**. Such patterns can be found in **medium-range data**. Also called **double exponential smoothing,** both the estimate for the average and the estimate for the trend are **smoothed**, two smoothing constants being used.

5. **Linear regression.** This is a model that uses what is called the **least squares method** to indentify the relationship between a dependent variable and one or more independent variables that are present in a set of historical observations. In **simple regression** there is only one independent variable. In **multiple regression** there is more than one independent variable. If the historical data set is a **time series**, the independent variable is the **time period** and the dependent variable in sales forecasting is **sales**. A regression model does not have to be used on a time series; in such cases the knowledge of future values of the independent variable (which may also be referred to as the *causal variable*) is used to predict future values of the dependent variable. Linear regression is ordinarily used in **long-range** forecasting, but if care is used in selecting the number of periods included in the historical data and that data set is projected only a few periods into the future, regression may also be appropriately used in short-range forecasting.

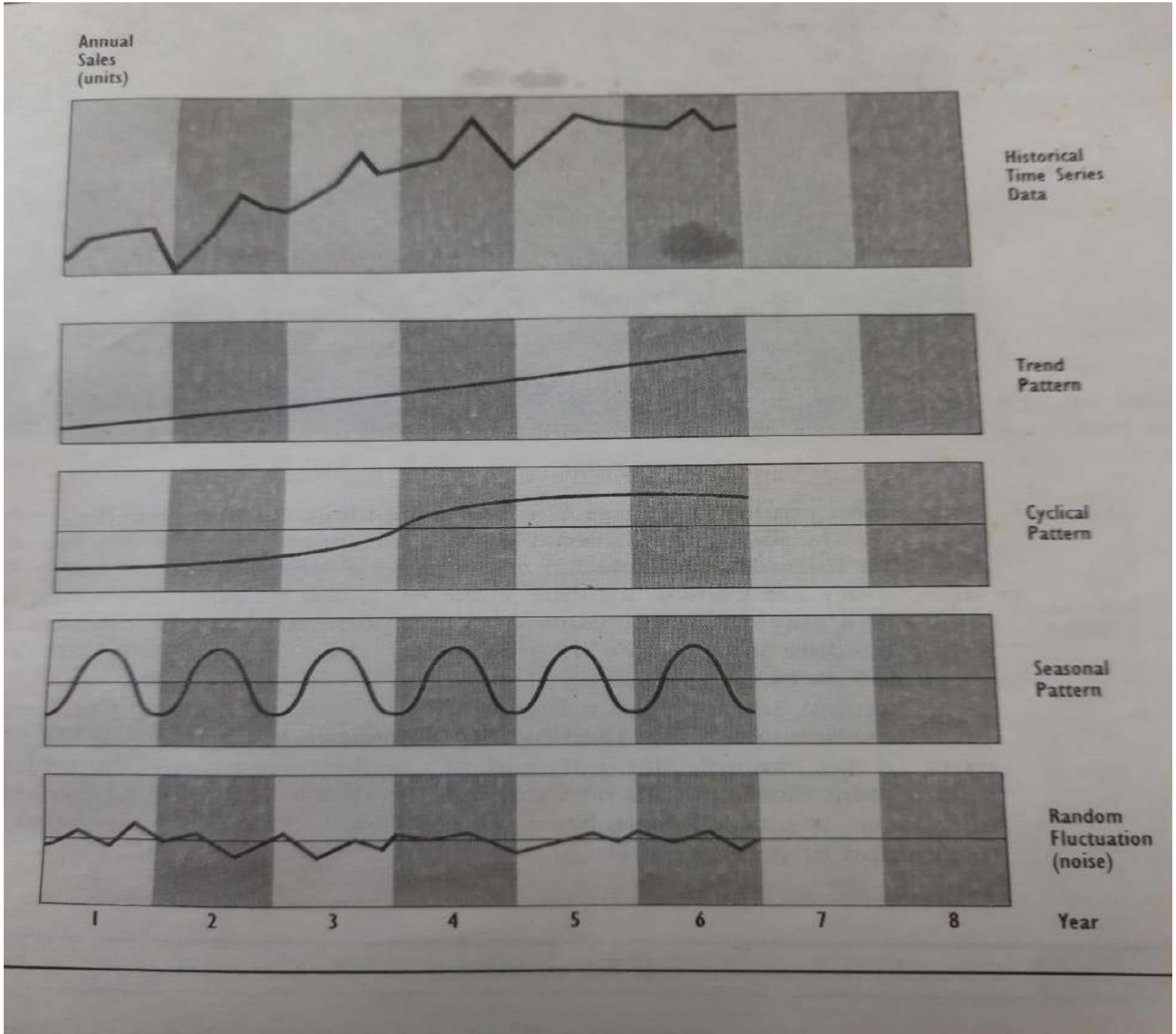
Long Range Forecasts

Long-range forecasting means estimating future conditions over time spans that are usually **greater than one year**. Long range forecasts are necessary in OM to support **strategic decisions** about planning products, processes, technologies, and facilities. Such decisions are so important to the long term success of the production/operations system success that **intense organizational effort** is applied to developing these forecasts.

Data patterns in long range forecasting/ Components of Time series

Although long range data **may look erratic**, keen observation reveal rather **simple underlying data patterns**. The following figure shows how historical sales data tend to be made up of several **components** like trends (T), cycles (C), seasonality (S), and random (R) fluctuations or noise. Long range **trends** are illustrated by an upward or downward sloping line. A **cycle** is a data pattern that may cover ***several years*** before it repeats itself again. **Seasonality** is a data pattern that repeats itself after a period of time, usually ***one year***. **Random fluctuation** or **noise** is a pattern resulting from random variation or unexplained causes. In the classical model of Time series analysis, the forecast is a multiplicative function of these components.

Forecast = TCSR


Annual Sales (units)
Historical Time Series Data
Trend Pattern
Cyclical Pattern
Seasonal Pattern
Random Fluctuation (noise)
1
2
3
4
5
6
7
8
Year

FORECASTING PROCEDURE

1. Plot the historical data to confirm the type of relationship (for example, linear, quadratic).
2. Develop a trend equation to describe the data.
3. Develop a seasonal index (if desired).
4. Project the trend into the future.
5. Multiply the monthly trend values by the seasonal index.
6. Modify the projected values by a knowledge of:

   a. Cyclical business conditions (C).

   b. Anticipated random/irregular effects (R).

Whenever long-range forecasts are to be made using historical time series data, **plotting the data** is often helpful in deciding which forecasting methods to consider. Different patterns can be clearly viewed from the **resulting graph**. In the above figure, six years of historical sales data are plotted on the top graph. Long-range forecasts could be developed by graphically fitting a line through these past data and extending it forward into the future. The sales forecasts for the periods 7 and 8 could then be read off the graph. This graphical approach is generally used in practice, but its principal drawback is the **inability to accurately fit a line** through the past data. **Regression analysis** provides a more accurate way to develop **trend line** forecasts.

Problems on simple linear regression analysis

Problem 1. An XYZ company produces sugarcane juice making machines that are sold all over the India. The company's production facility has operated at near capacity for over a year now. Its manager thinks that sales growth will continue, and he wants to develop long range forecasts to help plan facility requirements for the next 3 years. Sales record for the past 10 years have been compiled:

Year	Annual sales (thousands of units)	Year	Annual sales (thousands of units)
1	1000	6	2000
2	1300	7	2200
3	1800	8	2600
4	2000	9	2900
5	2000	10	3200

Problem 2. A general manager of Precision Engineering Corporation, thinks that his firms engineering services supplied to highway construction firms are directly related to the amount of highway construction contracts let in his geographic area. He wonders if this is really so and if it is, can this information help him plan his operations better? He asked one of his engineers, to perform a simple linear regression analysis on historical data to predict the level of demand for the next four quarters and determine how closely demand is related to the amount of construction contracts released. The data obtained for the past two years by quarters on both the demand of firms services and the total contracts released is as presented below. Also, to estimate the level of demand for the next four quarters, the estimates from the Contracting agencies for next four quarters are obtained as 260, 290, 300, and 270.

Year	Quarter	Sales of Precision Engineering Services (thousands of dollars)	Total amount of contracts released (thousands of dollars)
1	Q1	8	150
	Q2	10	170
	Q3	15	190
	Q4	9	170
2	Q1	12	180
	Q2	13	190
	Q3	12	200
	Q4	16	220

Problem 3. The manager of XYZ company producing sugarcane juice making machines is trying to plan cash, personnel, and material and supplies requirements for each quarter of next year. The quarterly sales data for the past three years seem to reflect fairly the seasonal output pattern that should be expected in the future. If the manager could estimate quarterly sales for next year, the cash, personnel, and materials and supplies needs could be determined. The past three years data is presented as follows:

Year	Quarterly Sales (thousands of units)			
	Q1	Q2	Q3	Q4
8	520	730	820	530
9	590	810	900	600
10	650	900	1000	650

Problem 4. Use the least squares method to develop a linear trend equation for the data shown below. And forecast a trend value for the year 1992.

Year	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Shipments (tons)	2	3	6	10	8	7	12	14	14	18	19

Short Range Forecasts

Short-range forecasts are usually estimates of future conditions over time spans that range from a few days to several weeks. These forecasts may span such short periods of time that cycles, seasonality, and trend patterns have **little effect**. The main data pattern affecting these forecasts is **random fluctuations**.

Short range forecasts provide operations managers with information to make such decisions as these:

•How much inventory of a particular product should be carried next month?

•How much of each product should be scheduled for production next week?

•How much of each raw material should be ordered for delivery next week?

•How many workers should be scheduled to work on overtime basis next week?

Forecast Accuracy

Forecast accuracy refers to how close forecasts come to actual data. Because forecasts are made *before* actual data become known, the **accuracy of forecasts** can be determined only after the passage of time. If forecasts are very close to the actual data, we say that they have **high accuracy** and that the **forecast error** is low. We determine the accuracy of forecasting models by keeping a running tally of how far forecasts have missed the actual data points over time. If the accuracy of a model is low, we **modify** the method or select a **new one.**

Measures of forecasting accuracy:

Three measures of forecasting accuracy are commonly used:

1. Standard error/deviation of the forecast (S_{yx}), is a measure of how historical data points have been dispersed about the trend line.
2. Mean squared error (MSE), which is simply $(S_{yx})^2$
3. Mean absolute deviation (MAD) = (Sum of the absolute value of **forecast error** for n periods)/n
4. Bias = (Sum of forecast error for n periods)/n; Unlike MAD, Bias indicates the directional tendency of forecast errors. If the forecast repeatedly overestimates actual demand, Bias will have a positive value and consistent underestimation will be indicated by a negative value.

Forecast error = forecasted demand – actual demand

If all these values are small, the actual data closely follow the forecasts of the dependent variable and the forecasting model is providing accurate forecasts. The relationship between MAD and S_{yx} are expressed as

$$S_{yx} = 1.25MAD$$

Problem 5: An aluminium extruder forecasted the demand for a shower stall extrusion to be 500 per month for each of three months. The actual demands turned out to be 400, 560, and 700. calculate forecast errors, MAD, and Bias.

Different Forecasting methods for Short-Range Forecasting

Simple average: It is the average of the demands occurring in all previous periods which are equally weighted.

Moving Average Method (MA):

A moving average is obtained by summing and averaging the values from a given number of periods repetitively, each time deleting the oldest value and adding a new value.

Weighted Moving Average Method (WMA):

This is an adjustment to the MA method. It allows one to vary the weights assigned to components of the moving average; in this way the most recent values can be emphasized. Weights can be percentages or any real numbers.

Exponential Smoothing:

It is a type of moving average forecasting technique which weighs past data in an exponential manner. Simple exponential smoothing makes no explicit adjustment for trend effects, whereas adjusted exponential smoothing does take trend effects into account.

Simple Exponential Smoothing: With simple exponential smoothing, the forecast is made up of the last-period forecast plus a portion of the difference between the last-period actual demand and the last-period forecast.

$$F_t = F_{t-1} + \alpha(D_{t-1} - F_{t-1})$$

where α = smoothing constant = 2/(n+1), where n is number of periods

Problem 6: The demand for ice coolers for past six months is given below. Forecast the July sales using 3 month Moving Average. Comparing it with a 6 month moving average (or simple average), which would be better? Also, forecast the demand for July using a three period model with the most recent periods demand weighted twice as heavily as each of the previous two periods demand is.

Month	Jan	Feb	Mar	April	May	June
Ice Coolers Demanded	200	300	200	400	500	600

Problem 7: A food processor uses a moving average to forecast next months demand. Past actual demand (in units) is as shown in the following table.

a. Compute a simple 5-month MA to forecast demand for month 52.

b. Compute a weighted 3-month MA where the weights are highest for the latest months and descend in order of 3, 2, 1.

Month	43	44	45	46	47	48	49	50	51
Actual Demand	105	106	110	110	114	121	130	128	137

Problem 8: A firm uses simple exponential smoothing with $\alpha = 0.1$ to forecast demand. The forecast for the 1st week of February was 500 units, whereas actual demand turned out to be 450 units.

a. Forecast the demand for the 2nd week of February.

b. Assume that the actual demand during 2nd week of February turned out to be 505 units. Forecast the demand for the 3rd week of Feb. Continue on forecasting through 3rd week of March, assuming that subsequent demand were actually 516, 488, 467, 554, and 510 units.

Problem 9: A shoe manufacturer, using exponential smoothing with $\alpha = 0.1$, has developed a January trend forecast of 400 units of shoes. This brand has seasonal indexes of 0.8, 0.9, and 1.20, respectively, for the first three months of the year. Assuming actual sales were 344 units in January and 414 in February, what would be the seasonalized (adjusted) March forecast?

Problem 10: Demand for a part was 200 in April, 50 in May, and 150 in June. The forecast for April was 100 units. With a smoothing constant of 0.2 and using simple exponential smoothing, what is the July forecast? Is 0.2 a good choice as a smoothing constant?

Operations Management

Course Teacher

Dr. Sricharan

Mechanical Engineering Department

S. R. K. R. Engineering College, Bhimavaram

III/IV 2 Semester 2022-2023

UNIT 2

Facility/Plant Location

- Introduction
- Factors affecting Plant Location
- Rural vs. Urban sites

Facility/Plant Layout

- Introduction
- Objectives of plant layout
- Determinants and Types of layouts
- Comparison of layouts for goods and services.

UNIT 2 – PLANT/FACILITY LOCATION & LAYOUT

Introduction to Plant/Facility Location

Definition: A Facility or a Plant is a place where all the inputs to the operations/production system like, men, materials, money, equipment, machinery, etc. are brought together for converting them into outputs like, products and services. In other words it is a place where the conversion of inputs to outputs takes place.

The problem of Facility location arises when starting a **new concern** or during the **expansion** of the existing plant. The decisions on facility location are not made lightly. They usually involve **long and costly studies** of **alternative** locations before the eventual site is selected. Those who have been through several of these location studies generally conclude that there is **no clear-cut best location**, but rather there are several good locations. Each location has its own strengths and weaknesses and the location decision becomes a **trade-off decision.** Location decisions can be better understood by examining the **factors that commonly affect** the final selection of facility locations.

Selecting a facility location usually involves a **sequence of decisions** including deciding on suitable nation, suitable region, and finally the **suitable site** within that region from where the plant will start functioning. Facility location plays a **major role in the design** of production/operations system as it determines the **cost of**

a. Getting suitable raw material;

b. Processing raw material to finished goods; and

c. Finished products/services delivering to customers.

Note: The possible questions from this slide are “Discuss the concept of facility location”, “What is the importance of facility location decision?” (or) “What is the need of facility location planning?”, and ““Location decision is a trade-off decision”- why? Elaborate.”

Factors Affecting/Governing Location Decisions

Facility/Plant Location decisions can be better understood by examining the **factors that commonly affect** the final selection of facility locations, which are discussed below. Of course, the **relative importance of each factor** depends upon the **type of firm**.

1. **Nearness to raw material.** It will reduce the cost of transporting raw material from the vendors end to the plant. Especially those plants, which consume raw material in **bulk,** or raw material is **heavy**, is **cheap but loses a good amount of weight** during processing (trees and saw mills), must be located close to the source of raw material.
2. **Transport facilities.** A lot of money is spent for both inbound transportation (raw material to factory) and outbound transportation (finished goods to market). Depending on the **size of raw material and finished goods**, a suitable method of transportation like roads, rail, water or air is selected and accordingly the plant location is selected. One must keep in mind that cost of transportation should remain fairly small in proportion to the total cost.
3. **Nearness to market.** It reduces the cost of transportation as well as the chances of the finished goods getting damaged and spoiled in the way (especially perishable products). Moreover a plant being near to the market can catch a big share of the market and can render quick service to the customers.
4. **Availability of fuel and power.** Because of the widespread use of electric power, in most cases fuel, (coal, oil, etc.) has not remained a deciding factor for plant location. Even then steel industries are located near source of fuel (coal) to cut down the fuel transportation costs.

   It is of course essential that electric power should remain available continuously, in proper quantity and at reasonable rates.

6. **Availability of water.** Water is used for processing , as in paper and chemical industries, and is also required for drinking and sanitary purposes. Depending on the nature of the plant, water should be available in adequate quantity and should be of proper quality (clean and pure). A chemical industry should not be set up at a location which is famous for water shortage.
7. **Climatic conditions.** With the developments in the field of heating, ventilating and air-conditioning, climate of the region does not present much problem. Of course, control of the climate needs money.
8. **Land.** Topography, area, the shape of the site, cost, drainage and other facilities, the probability of floods, earthquakes (from the past history) etc. influence the selection of plant location.
9. **Financial and other aids.** Certain states give aids as loans, feed money, machinery, built up sheds, etc. to attract industrialists.
10. **Community attitude.** Success of an industry depends very much on the attitude of the local people and whether they want work or not.
11. Presence of related industries.
12. Existence of marketing centres, hospitals, schools, banks, post offices, clubs, etc.
13. Local bye-laws, taxes, building ordinances, etc.
14. Housing facilities.
15. Security.
16. Facilities for expansion.

One may always wonder for the reasons why one type of company is located near its raw materials while another is located near its customers? And why would companies that are obvious competitors locate right next door to one another? These questions suggest that each type of company has a **few dominant factors** that ultimately determine its facility locations decisions. To state it more elaborately, let us look at the following examples.

Mining, quarrying, and heavy manufacturing have **capital intensive** facilities that are expensive to build, cover large geographic areas, and use great quantities of heavy and bulky raw materials. Additionally, their production processes discard **large amounts of wastes**, total finished outputs weigh much less than total raw material inputs, **enormous quantities of utilities** are absorbed, and products are shipped only to a **few customers**. These facilities consequently tend to be located near raw material sources rather than near their markets so as to minimize the total transportation costs of inputs and outputs. Additionally, they tend to select sites where **land and construction costs are relatively inexpensive** and where waste disposal is not expected to **harm the environment**. The availability of an abundant supply of **utilities** and the **proximity of railroad** service are also necessary.

Light manufacturing facilities make such items as electronic components, small mechanical parts, and assembled products. These facilities **do not necessarily** locate near either raw material sources or markets. Rather, they strike a **balance between** transportation costs of inputs and outputs, and other locational factors therefore tend to dominate the location decision. The **availability and cost of labour** is important in the location decisions of these facilities. Whereas transportation cost is of less importance. Of course. As the level of automation increases, this will no more be an important decision.

Note: Mining – Process of extracting useful materials from earth like, coal, gold, iron ore, etc.

Quarrying – The process of removing rock, sand, gravel, and other minerals from the ground in order to use them, to produce materials for construction or other uses.

The location of **warehouses** is perhaps the most straightforward location decision among the various types of facilities. The dominant factors are those affecting **incoming and outgoing transportation costs**. Although it is desirable and indeed frequently necessary to be near enough to markets to both communicate effectively with recipients of outgoing products and react quickly to customer orders, **transportation cost** is the **paramount** locational factor for warehouses.

The success and survival of **R&D and high-tech manufacturing companies** depend in large measure on their ability to **recruit and retain** scientists, engineers, and other professionals. The attractiveness of **community lifestyle and proximity to universities** are predominant factors in recruiting these employees.

Retailing facilities and customer services for profit are located near concentrations of **target customers.** All other locational factors are subordinate to this single factor. **Local government service facilities** also are usually located near concentrations of their constituents.

Health and emergency services are traditionally located near **concentrations of constituents** because the consideration in selecting locations is that such locations result in the lowest overall response times between the constituents and their services. The **minimizing** of property loss and loss of life is the overriding consideration in these locations. **Fire stations** are typically located near concentrations of residential constituents to minimize the time it takes for fire engines to arrive at fire scenes. Similarly, **hospitals** are usually located near the centres of community population density concentrations.

URBAN V/S RURAL SITES

Both the sites have their own advantages and limitations which are delineated as follows:

Selecting the plant site in a city (Urban site)

Advantages	Limitations
1. A city is well connected by rail, road, and air. 2. It provides a good a market also. 3. Right labour force is available. 4. Power and water is easily available. 5. It has good hospitals, marketing centres, schools, banks, recreation clubs, etc. 6. The factory can be set up in an existing available building. 7. Worker's and foremen's training classes and many other educational facilities can be found in cities. 8. Services of experts and specialists are easily available. 9. Many other small industries existing nearby can work as ancillaries. 10. Security is there.	1. Land available for the building is limited in area. 2. Cost of land and building construction is high. 3. Expansion of the industry is seldom possible. 4. Local taxes, etc., are high. 5. Labor salaries are high 6. Union problems are more and so employee-employer relations are not so good.

Selecting the plant site in small town or more or less a rural area.

Advantages	Limitations
1. Plenty of land is available for building construction and expansion purposes. 2. Land is cheap. 3. Unskilled labor is available which can be trained to suit the requirements of the concern. 4. Employee-employer relations are good; no union problem. 5. Undesirable manufacturing neighbor's are not likely to be present. 6. Municipal and other regulations and taxes etc., are seldom present. 7. Government gives inducements as it wants to develop the underdeveloped areas.	1. Skilled labor is not available. 2. Rail, road, and air links may not be there at all or may not be adequate. 3. Power is not available. 4. Rural areas are far from selling markets. 5. Hospitals, educational and amusement centers are not available. 6. Ancillary services cannot be obtained. 7. Expert and specialist advice is not available. 8. High grade executives may not like to live in rural areas.

An **alternative** between the urban and rural sites is the *Suburban site* which being a **compromise** between the two is probably the **most suitable**. It possess the good points of both urban and rural locations.

Introduction to Plant/Facility Layout

Definition: Facility Layout means **planning for the location** of all machines, utilities, employee workstations, customer service areas, material storage areas, aisles, rest rooms, lunch rooms, drinking water facilities, internal walls, offices, and computer rooms, and for the flow pattern of the materials and people around, into, and within buildings. This planning is an important component of a business's overall operations, both in terms of **maximizing the effectiveness of production process** and **meeting the needs of employees**.

Objectives of Facility/Plant layouts:

The following is the list of some objectives of facility layouts for manufacturing, warehouse, service, and office operations. The list is organized to show first the objectives for manufacturing operations, **which also apply to** warehouse, service, and office operations. Then the **additional objectives** for warehouse, service, and office operations are shown.

<u>Objectives for Manufacturing Operation Layouts</u>

•Provide enough production capacity

•Reduce material handling costs

•Conform to site and building constraints

•Allow space for production machines

•Allow high labour, machine, and space utilization and productivity

•Provide for volume and product flexibility

•Provide space for cafeterias, rest rooms, and other personal care needs of employees

•Provide for employee safety and health

•Allow ease of supervision

•Allow ease of maintenance

•Achieve objectives with least capital investment

<u>Additional Objectives for Warehouse Operation Layouts</u>

•Promote efficient loading and unloading of shipping vehicles

•Provide for effective stock picking, order filling (the process of delivering purchased items to intended customer), and unit loading

•Allow ease of inventory counts

•Promote accurate inventory record keeping

<u>Additional Objectives for Exchange Service Operation Layouts</u>

•Provide for customer comfort and convenience

•Provide appealing setting for customers

•Allow attractive display of merchandise (goods that are for sale)

•Reduce travel of personnel or customers

•Provide for stock rotation for shelf life

Additional Objectives for Office Operation Layouts

•Reinforce organization structure (grouping of employees)

•Reduce travel of personnel or customers

•Provide for privacy in work areas

•Promote communication between work areas for proper flow of information

Determinants of Layouts

The type of layout is generally determined by the following:

Type of product. This concerns whether the product is a good or a service, the product design and quality standards, and whether the product is produced for stock or for order.

Type of production process. This relates to the technology used, the type of materials handled, and/or the means of providing the service.

Volume of production. Volume affects the present facility design and capacity utilization, plus provisions for expansion or change.

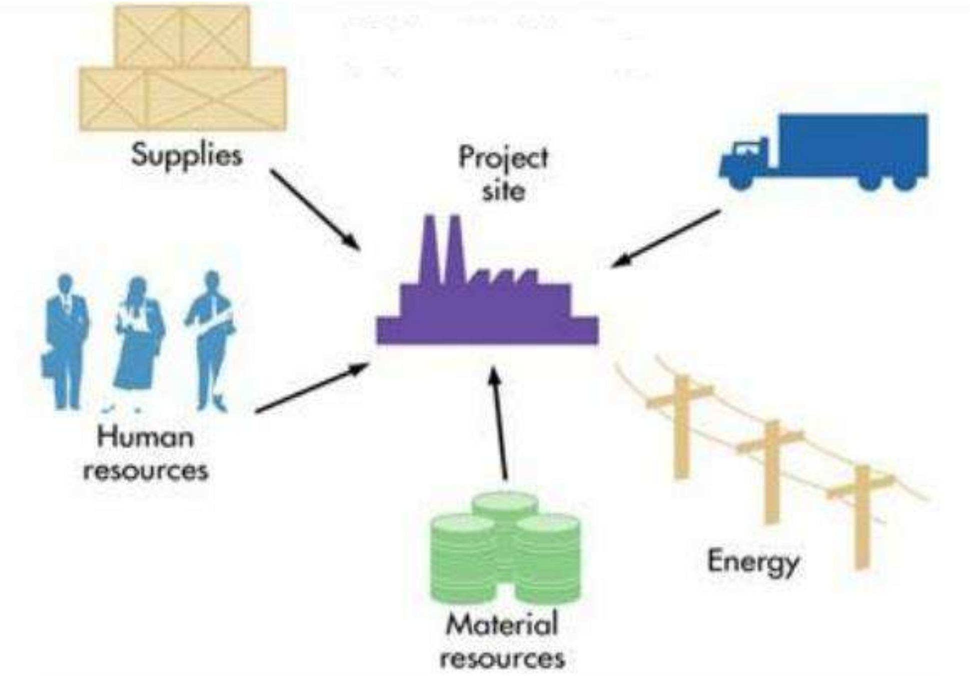
Note: Possible questions from this topic are "What factors determines the type of layout used in an organization?"

Types of Layouts

Although it is convenient to classify layouts into two or three basic types, in reality there is a **continuum** of different types of layouts which can be **combined in a variety of ways**. It is also not uncommon for organizations to use more than one type of layout within a given facility. Much of the theory underlying effective layouts applies **equally to goods and services**. However, in goods manufacturing, major concerns lie with the efficiency of the **flow of physical materials**, whereas with **services concerns** are more often with the **flow or satisfaction of customers**.

Fixed Position Layouts are perhaps the simplest type of layout. They are arrangements whereby labour and materials are brought to the location where the work is done. Managerial skills, workers, subcontractors, and materials are all brought to a job site. Custom design, building, and construction projects are often done on this basis. These layouts are used when the product is very bulky, large, heavy, or fragile. Examples include homebuilding, ship building, dam construction, missile assembly, etc.

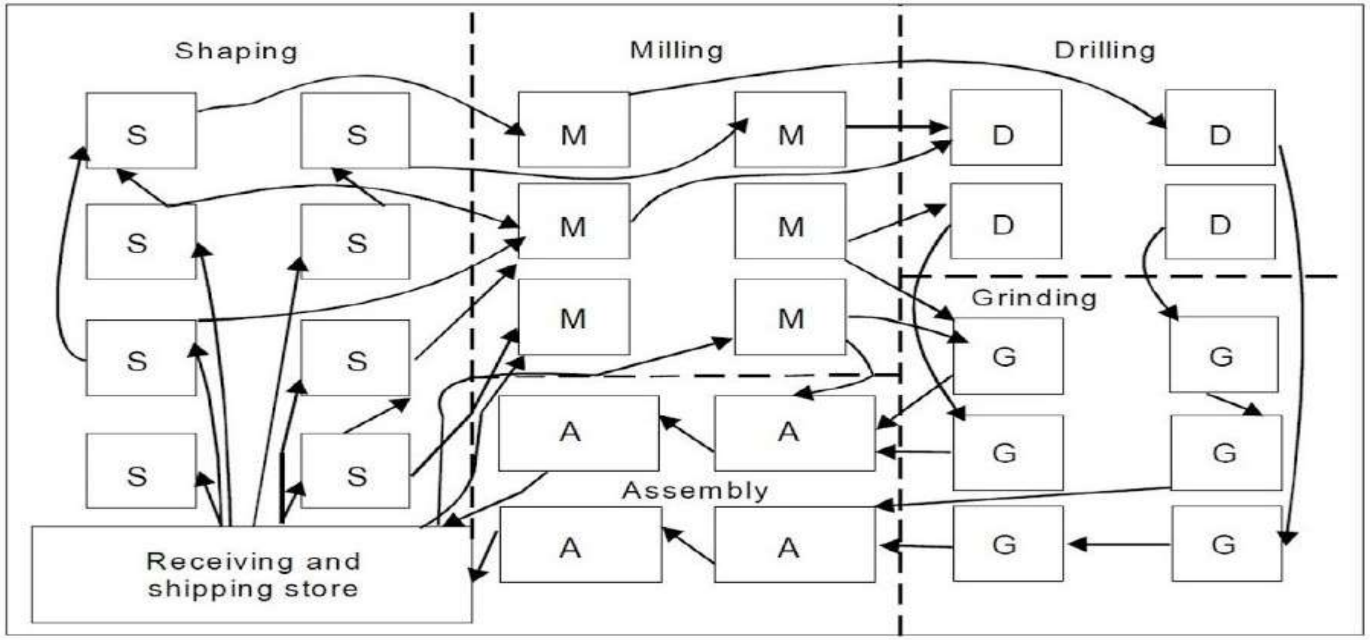
It has the **advantage** of minimizing the handling costs of the end product. **However,** the cost of attracting the skilled personnel to the job site may be high, support facilities are sometimes limited, and expensive equipment may not be as fully utilized as with other types of layouts.



Job Shop Layouts are arrangements that **group the people and equipment performing similar functions**. They are sometimes referred to as **process layouts** or **functional layouts** because specific functions, such as inspection, drilling, painting, or x-raying, are performed in **one location for various products**. Machine shops, hospitals, banks, universities, libraries, carnivals, etc., have these layout characteristics.

They have **advantages** of 1. being flexible to do custom work, 2. promoting job satisfaction by offering employees diverse and challenging tasks, and 3. limiting investment in highly specialized, high volume equipment.

Disadvantages are the higher costs of 1. materials handling, 2. skilled labour (coupled with a lower productivity because of the uniqueness of each job), and 3. more complex production control. Because the work flow is **intermittent**, each job must be **individually routed** through the system and scheduled at various work centres. All the special drawings, tools, and equipment setups must be individually arranged for, and the status of each job must be monitored.



Batch processing layouts Job shops that process large orders of identical units as a group through the same production sequence are employing principles of batch processing. Batch processing layouts enable producers to achieve some **economies of scale** by performing the same activities on conveniently managed volumes (or batches) of product. Batch processing is used for a wide range of goods and services like baked goods, clothing, cricket bats, furniture, computer chips, credit card transactions, NEFT transactions in banks, etc.

Line processing layouts are arrangements of people and equipment according to the **sequence of operations** that are performed on the product or for the customer. They are sometimes called ***product line (or assembly line) layouts*** because they lend themselves to the use of **straight-line conveyors and automated equipment**, which minimizes the amount of manual material handling. Automobile assembly plants, food processing plants, and cafeterias are examples of line layouts. In some service facilities such as cafeterias, the customer, rather than a physical product, moves down the line. This facility layout is designed to produce large volumes of a single item (or relatively few items) on **specialized fixed path equipment** and has a **continuous work flow.**

Line layouts offer the **advantages** of 1. lower material handling costs, 2. simplified tasks that can be done with low-cost, unskilled labour, 3. reduced amounts of work-in-process inventory, and 4. much simplified production control activities.

Disadvantages of the line layouts are their 1. inflexibility, 2. high fixed costs of investment in specialized equipment, and 3. heavy interdependence of all operations. A break down in one machine or an uncompleted task at one work station can idle much of the equipment and reduce or halt the total production output. The proper balancing of the capacities of workers and work stations is a major consideration.

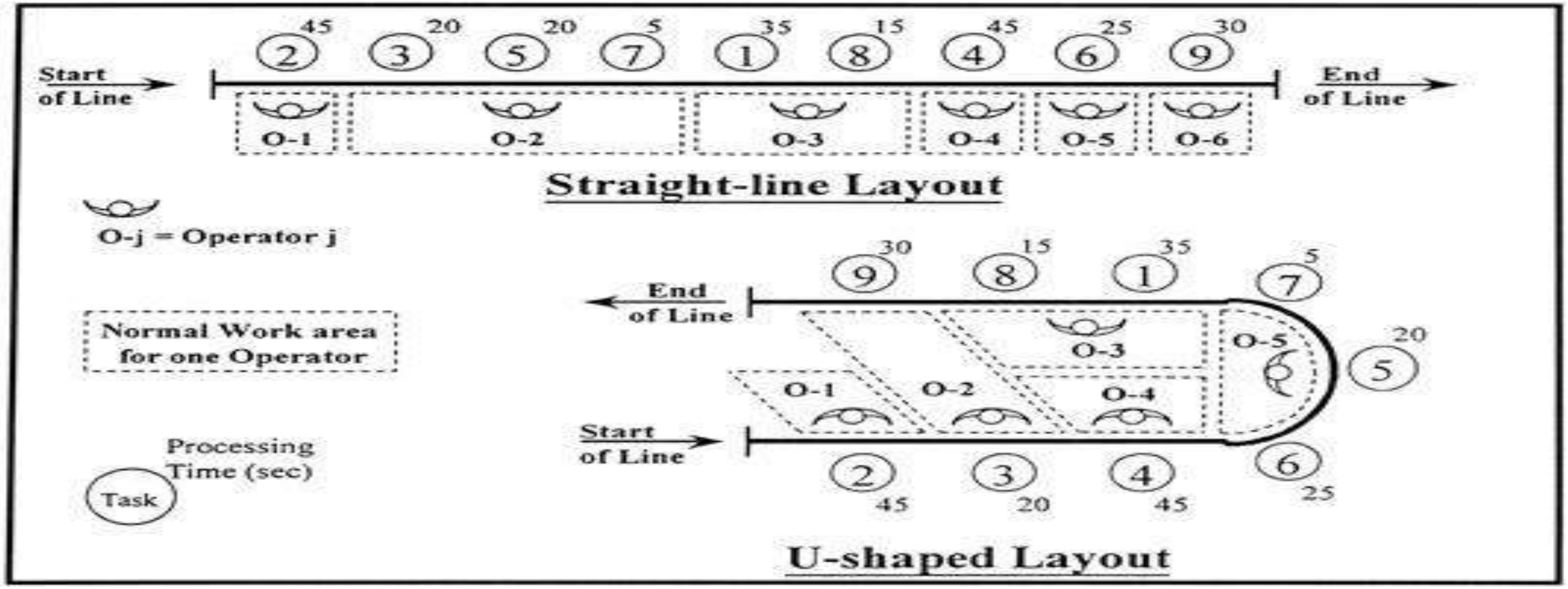


Figure: Product line or Assembly line layout (Line Processing Layouts)

Continuous Flow Layout. While Line Layouts are for the production of **discrete parts**, Continuous Flow Layout is for the purpose of **seamless production** like in the case of production of chemicals, paint, petroleum, or electricity. The processing facilities (which may represent a substantial capital investment), are often highly automated and designed to operate as **one integral unit**. Plant layout here is largely an engineering design function, and there is **little flexibility** for change except via a design modification to the plant.

Hybrid Layout. Most manufacturing facilities use a combination of layout types. As an example consider the final assembly of Boeing's commercial aircraft. During final assembly, each aircraft unit is located in a fixed position assembly bay. However, every two or three days. Each aircraft unit is rolled out of its bay and pushed into the next assembly bay, where different assembly tasks are performed. So, even though an aircraft is assembled for two or three days at a time in a **fixed position**, it passes through six or eight different assembly bays in **a product layout fashion**.

Cellular Manufacturing Layout. In Cellular Manufacturing (CM), machines **grouped** into cells like that of a job shop or process layout, and the cells **function** somewhat like a product layout. This is somewhat like a **product layout within a process layout**. Here each cell is formed to produce a **single parts family** based on **Group Technology**, in which items are grouped according to their **commonality** in their **design** or in their **manufacturing** that would enable the equipment to **capitalize** on the **similar processing activities**. In other words, parts family means, a few parts all with common characteristics, which usually means that they require the **same machines** and have **similar machine settings**.

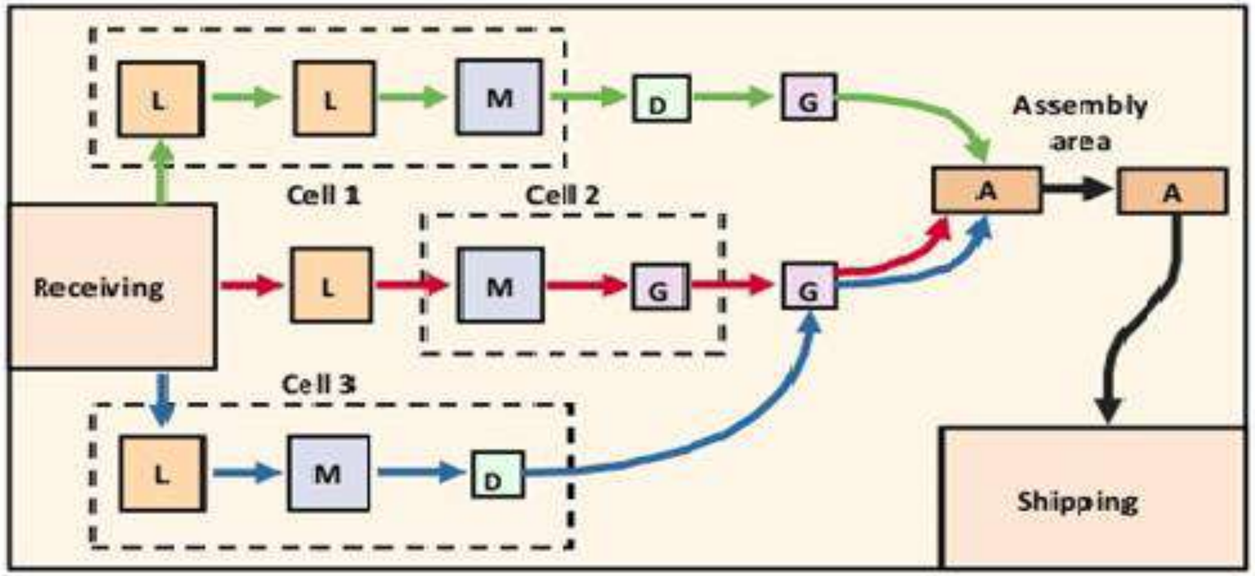


Figure: Line flows in a Job shop with 3 GT cells

CM Layout would be attempted for these reasons:

1. Machine changeovers are simplified.
2. Cells are typically connected with material handling equipment and so these costs are reduced.
3. Parts can be made faster and shipped more quickly.
4. Less work in process inventory is required.
5. CM Layout can be expanded toward a FMS by adding a supervisory computer and more machines as investment funds become justified.

In developing a CM Layout, the first step is the **cell formation decision,** the initial decision about which production machines and which parts to group into a cell. **Next,** the machines are arranged within each cell.

Flexible Manufacturing Systems (FMS) are production systems that include a supervisory computer, plus automated machine tools and automated material handling equipment. The tools and handling equipment can **follow the computer's** instructions to produce hundreds of different parts in whatever **order is specified**. Items are thus loaded, processed, assembled, and inspected **without being transported** to different processing centres throughout the plant.

By producing exactly what is needed, companies with FMSs can keep their inventories very low (goods arrive "just in time" to support other needs) and minimize their work-in-process costs. The FMSs also reduce labour costs and improve productivity. Finally, help ensure a consistently high level of product quality as the system will automatically reject any defective parts. However, FMSs installations are costly.

Comparison of layouts for goods and services

Layouts do not usually conform to the classifications described above in all respects. For example, behind the picturesque, smooth running automobile assembly lines have job and batch processing shops (i.e. apart from the regular assembly line) for producing the needed components and subassemblies. And some of these production activities are highly automated whereas others are not.

Similarly service systems also blend characteristics of job shop, batch, and line processing layouts. At one end of the spectrum, **hospitals** make full use of the **job shop characteristics**. Patients (instead of materials) are uniquely routed to different "work centres" for customized x-rays, ECGs, blood tests, surgery, and so forth. Like **machine shops,** many service facilities also rely on queues to regulate the flow of customers. The empty hospital beds, idle fire engines, and unfilled airline seats represent the costs of idle capacity, much as idle machines do in a manufacturing plant. But as the services offered become **more standardized**, characteristics of **continuous flow emerge** like in the case of customers entering **movie theatres** in batches.

A fast food service facility incorporates some characteristics of both job shop and line processing. Here the customers select from a limited menu so their food is provided "**to order**". Still, the customers themselves move down the "**service line**". Individual persons stop at the tables, where a large in-process storage-consumption area must be provided, just as for **in-process inventories** in batch or line layouts.

Line processing and continuous flow **service systems** also capitalize on the same economies of scale (high volume and low processing costs) as manufacturing systems. And as the service become highly standardized, the "tailored" nature of the service (or the marketing strategy) shifts to choices concerning the time and quantity of service desired. The use of electricity, phone service, computer banking illustrates this shift. An increasing number of these continuous flow type services are information and/or communications oriented. So the "layout strategies" here focus on better ways of making the service available wherever and whenever the customer wants it.

Operations Management

Course Teacher

Dr. Sricharan

Mechanical Engineering Department

S. R. K. R. Engineering College, Bhimavaram

III/IV 2 Semester 2022-2023

UNIT 3

Aggregate Planning

- Overview of Operations Planning and Scheduling system
- The concept of aggregation and goals for aggregate planning
- Costs associated with aggregate planning
- Aggregate planning Guidelines
- Aggregate planning strategies

Master Scheduling

- Master Scheduling – Introduction and Functions
- Guidelines of Master Scheduling
- Assembly v/s Process industry scheduling
- Difference between Master Scheduling and Shop Floor Scheduling.

UNIT 3 – AGGREGATE PLANNING & MASTER SCHEDULING

Overview of Operations Planning and Scheduling system

Operations Planning and Scheduling **systems** concern the volume and timing of outputs, the utilization of operations capacity, and balancing outputs with capacity at desired levels for competitive effectiveness. These systems must fit together activities at various levels, from **top to bottom**, in support of one another, as shown in the **Figure** in next slide. Note that the **time orientation** ranges from long to short as we progress from top to bottom in the hierarchy. Also, the **level of detail** in the planning process ranges from broad at the top to detailed at the bottom.

Before going into the **detailed concepts** of Aggregate Planning and Master Production Schedule, which are at the **top level** of the "Operations Planning and Master Scheduling System", let us look at the overview of this entire system (shown in the **Figure** in next slide) to get the overall picture.

The Business Plan. The *Business Plan* is a statement of the organizations **overall level of business activity** for the coming **6 to 18** months, usually expressed in terms of **outputs** (in Rupees/Dollar volumes of sales) for its **various product groups**. This plan is developed at the top executive level and is based on forecasts and competitive considerations.

The business plan, in a sense, is an **agreement between all** functional areas – finance, production, marketing, engineering, R&D – about the level of activity and the products they are committed to support. It is **not concerned** with all the **details and specific timing** of the actions for executing the plan. Instead, it determines a **feasible general posture** for competing to achieve its major goals. The resulting plan **guides the lower level**, more detailed decisions.

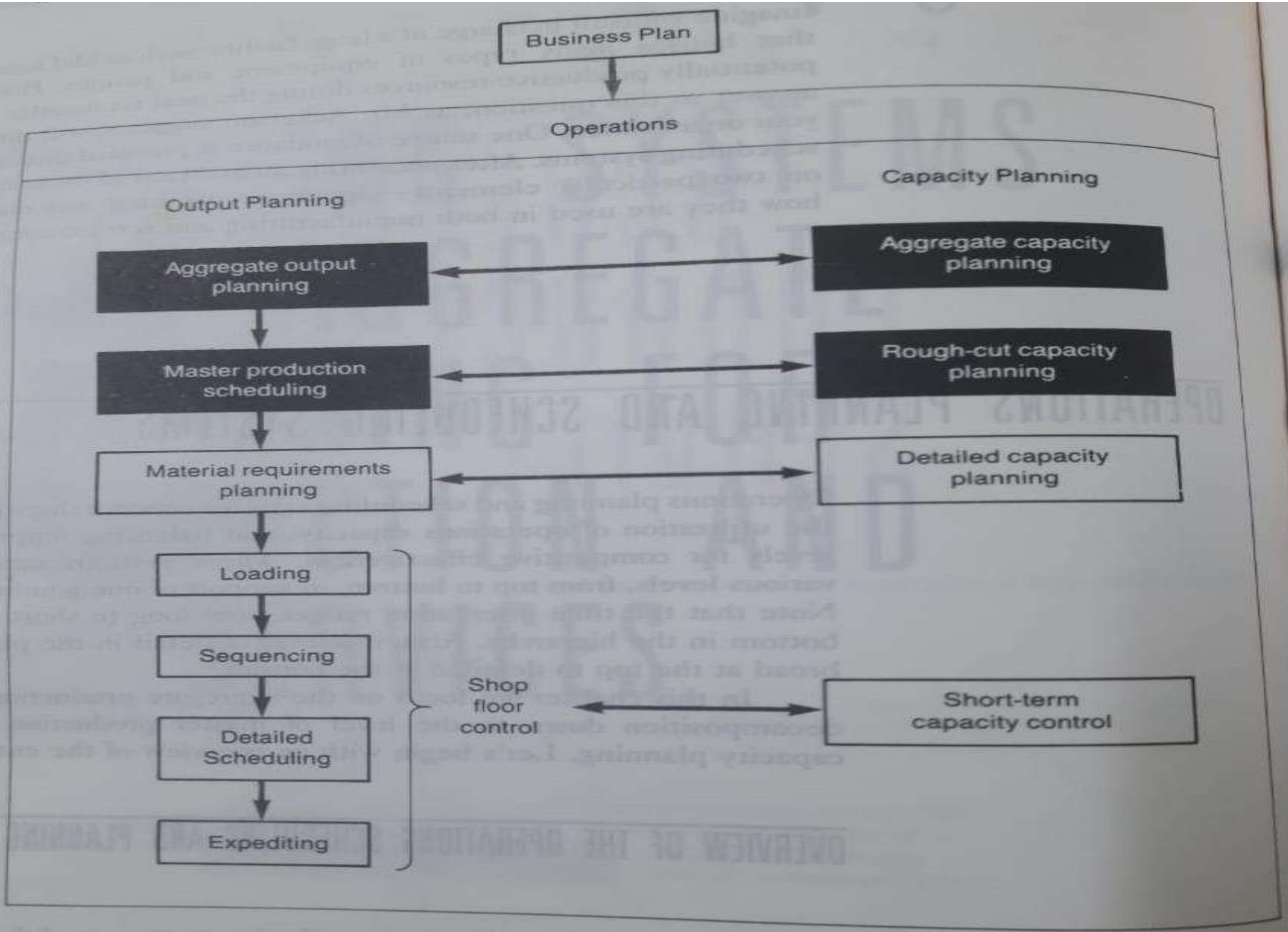


FIGURE 10.1 The operations planning and scheduling system

Aggregate Production (Output) Planning. This plan is the **production portion** of the business plan and is the process of determining output levels (units) of various product groups over the coming 6 to 18 months on a **weekly or monthly** basis. Since various product groups may be produced at diverse plants, facilities, or divisions, each of them needs its **own production/output plan**. Planning at this level **ignores such details** as how many of each individual product, style, colour, or model to produce. The plan **recognizes** the division's existing fixed capacity and the companies overall policies for maintaining inventories, employment stability, and subcontracting.

Aggregate Capacity Planning. This is the process of testing the **feasibility** of aggregate output plans against the existing capacity and evaluating overall **capacity utilization** to keep it at desired levels. Similar to aggregate output plans, **each plant**, facility, or division requires its own aggregate capacity plan. Capacity and output must be in **balance**. A product group, for example, usually consumes predictable amounts of **capacity such as** labour hours of assembly or machine hours of fabrication. Although these basic capacities are fixed, management can **manipulate** the short-term capacities by the ways they deploy their workforce, by subcontracting, or by using multiple work shifts to adjust the timing of overall outputs. As a result, the **aggregate planning process** balances output levels, capacity constraints, and temporary capacity adjustments to meet demand and utilize capacity at desired levels during the coming months. The resulting plan sets the limits for the Master Production Schedule (MPS).

Master Production Schedule. The purpose of MPS is to meet the demand for **individual** products in the product group. This more detailed level of planning ***disaggregates*** the product groups into individual products and indicates **when t**hey will be produced. In other words, it is a schedule showing **week by week** how many of each product must be produced according to customer orders and demand forecasts.

Aggregate Plan

Month	J	F	M	A	M	J	J	A	S
Number of Motors	40	25	50	30	30	50	30	40	40

Master Schedule

Month	J	F	M	A	M	J	J	A	S
AC motors:									
5 hp	15	—	30	—	—	30	—	—	10
25 hp	20	25	20	15	15	15	20	20	20
DC motors:									
20 hp	—	—	—	—	—	—	10	10	—
WR motors:									
10 hp	5	—	—	15	15	5	—	10	10

Figure: Difference between an Aggregate Plan and MPS

Rough-Cut Capacity Planning (or) Resource Requirements Planning. This is done in **conjunction** with the tentative MPS to test its **feasibility** in terms of capacity before the MPS is finally settled. This step ensures that a proposed MPS does not inadvertently overload any key department, work centre, or machine, making the MPS unworkable. Although the check can apply to all work centers, it is typically applied only to the **critical ones** that are most likely to be **bottlenecks**. It is a quick and inexpensive way to find and **correct** gross discrepancies between the capacity requirements (in direct labor hours, for example) of the MPS and available capacity.

Material Requirements Planning (MRP). The MPS is the **driving force** for *material requirements planning*. MRP shows the **time phased** requirements for **releasing** materials and **receiving** materials that enable the MPS to be implemented.

Detailed Capacity Planning (or) Capacity Requirements Planning. This is a companion process used with MRP to identify **in detail** the capacity required to execute the MRP. At this level, **more accurate comparisons** of **available and needed** capacity for scheduled workloads are possible.

Shop Floor Control. This coordinates the weekly and daily activities that get jobs done. Individual jobs are assigned to machines and work centers (loading), the sequence of processing the jobs for priority control is determined, start times and job assignments for each stage of processing are decided (detailed scheduling), and materials and work flows from station to station are monitored and adjusted (expediting). Coordinating all these activities into smooth flows, especially when unplanned delays and new priorities arise, often calls for last minute adjustments of outputs and capacities, the ***short-term capacity control***.

The concept of Aggregation

Aggregate planning is the process of planning the quantity and timing of output over the intermediate time horizon (6 months to 18 months). Within that time frame the maximum capacity of a production facility is relatively fixed. Given a forecast, planners are concerned with making the best possible use of the organization’s capacity (labor, materials, and other capital) resources to respond to expected demand – which might be either higher or lower than expected.

To develop an aggregate plan, managers must first identify a **meaningful measure of output**. This presents no problem for organizations with a single product because their outputs are measured directly by the number of units they produce. Most organizations, however, have several products, and a common denominator for measuring total output may not be so easy to find. The **term "aggregate"** is used because the production plans at this stage are expressed in homogeneous units of output, such as number of automobiles, tons of steel, gallons of paint. If it is service industries, the units of output can be patient visits for health care facilities and faculty-to-student contact hours for educational institutions.

Goals of Aggregate Planning

The aggregate plan must simultaneously satisfy a number of goals. **First,** it has to **provide the** overall levels of output and inventory **dictated** by the business plan. If the business plan calls for inventory buildup in anticipation of a major promotional campaign, the aggregate plan should provide for the appropriate production support. Similarly, the business plan may call for seasonal buildup or reduction, and this too must be provided for in the aggregate plan.

The **second** aggregate planning goal is to **use the facilities capacity** in a manner consistent with the organization's strategy. Under utilized capacity can be an expensive waste of resources. Therefore, a firm's strategy may well be to operate at near full capacity for efficient operations. Another company, however, (e.g., one competing on the basis of flexible service to customers), may keep a cushion of capacity for quick reaction to sudden surges in market demand. We can see, then, how the planned level of capacity use depends on the company's strategy.

Finally, the aggregate plan should be **consistent with the company's goals and policies regarding employees**. A firm may emphasize employment stability, especially where critical job skills are scarce, and therefore be reluctant to hire or lay off employees. Other firms change employees freely as the output level is varied throughout the aggregate planning horizon.

Costs associated with Aggregate Planning

To execute the Aggregate plan there can be range of alternatives **for capacity use** that can be considered by the management. Some of the alternatives could be as follows:

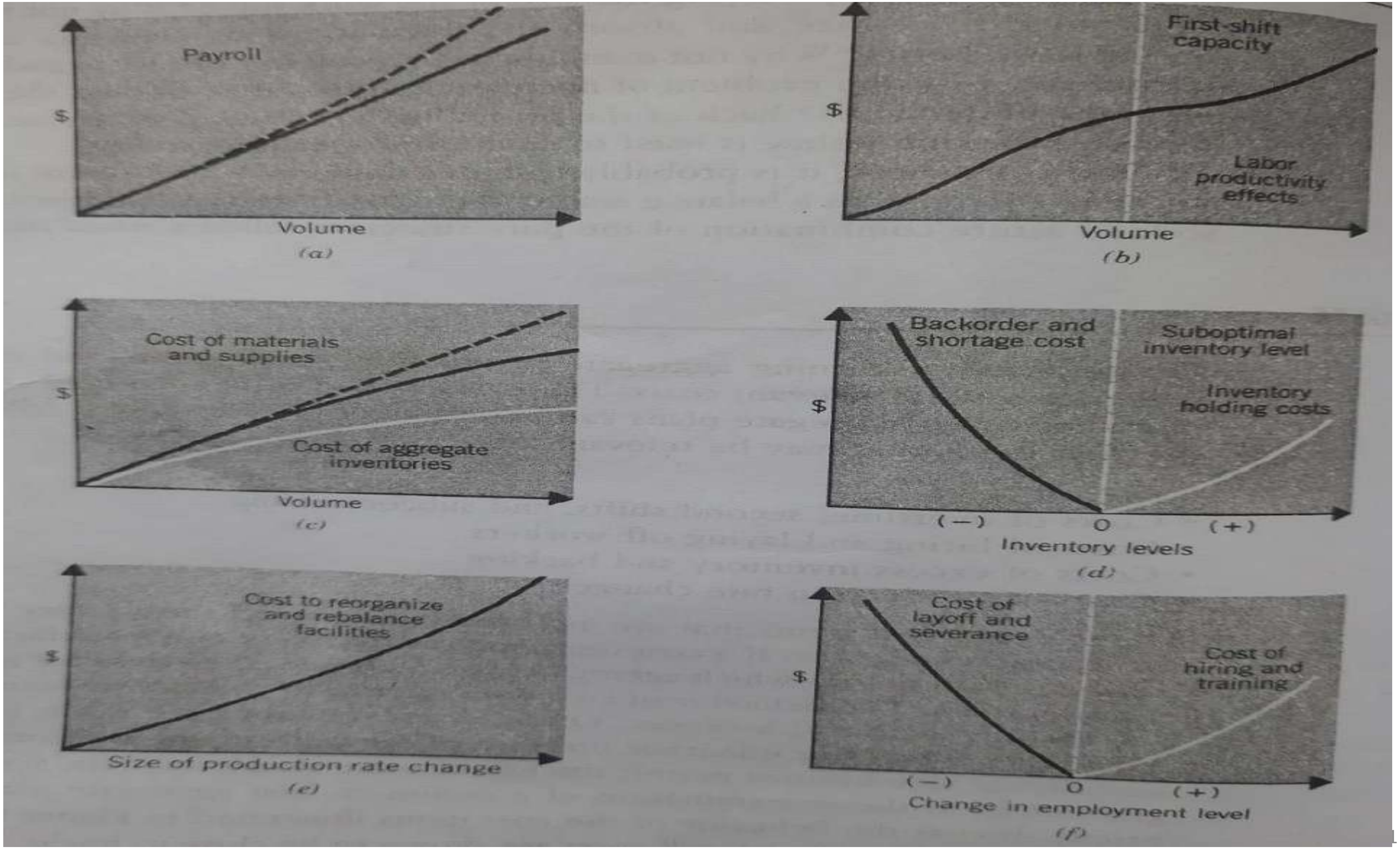
- To what extent should inventory be used to absorb the fluctuations in demand that will occur over the next 6 to 12 months?
- Why not absorb these fluctuations by simply varying the size of the work force?
- Why not maintain a fairly stable workforce size and absorb the fluctuations by changing activity rates by varying work hours?
- Why not maintain a fairly stable work force and let subcontractors wrestle with the problem of fluctuating order rates?

Each of these alternative strategies concerning aggregate production, work force, and inventory levels **influence** several relevant costs. These costs need to be identified and measured so that alternative aggregate plans can be evaluated on a **total cost criterion**. Some of the cost items that may be relevant are

- Payroll costs – Payroll expense is the amount of salaries and wages paid to employees in exchange for services rendered by them to a business. This includes EPF, ESI, Health and Education.
- Costs of overtime, second shifts, and subcontracting
- Costs of hiring and laying off workers
- Costs of excess inventory and backlog
- Costs of production rate changes

The selected cost items should **vary with changes** in decision variables. If a cost item, such as the salary of a manufacturing manager, is incurred no matter which aggregate plan is chosen, then this cost is **excluded** from the consideration. However, the behaviour of cost with respect to changes in decision variables is **not easy to quantify**. Often, approximations are made by assuming the costs to be a **linear or quadratic** function of the appropriate decision variable. These **simplifying assumptions** will help us to use some **simple mathematical models** to determine a **minimum cost aggregate plan**. Let us now discuss the behaviour of the cost items illustrated in the following **Figure**.

In Figure (a), the **payroll costs** are shown to be close to linear. This assumption is not appropriate if the stable workforce is maintained and the workforce is paid at higher rates for higher levels of production. In addition, the **productivity of labour** in relation to the volume of activities as shown in Figure (b), makes **labour cost per unit** a non linear function. In general, when some operations starts workers will exhibit some **start-up difficulties** that would be reflected in low output per worker hour. In the middle range of one shift operations, the curve may be approximately **linear**. But as we approach the limits of one shift, productivity falls because of increased **congestion**, interference, and delays. The same non linearity is exhibited even when we start second shift also.


Payroll
$
Volume
(a)
First-shift capacity
$
Labor productivity effects
Volume
(b)
Cost of materials and supplies
$
Cost of aggregate inventories
Volume
(c)
Backorder and shortage cost
Suboptimal inventory level
Inventory holding costs
$
(−)
0
(+)
Inventory levels
(d)
Cost to reorganize and rebalance facilities
$
Size of production rate change
(e)
Cost of layoff and severance
Cost of hiring and training
$
(−)
0
(+)
Change in employment level
(f)

In Figure (c), we see two cost components related to the material. We assume that the **cost of materials** would be linear in relation to volume (the dashed line), but quantity discounts and aggressive procurement staff should produce economies at higher volumes (the solid line). As volume goes up, the size of the aggregate inventory (i.e. the **cost of aggregate inventory**) necessary to maintain the production-distribution process increases also, but not in direct proportion.

In Figure (d), we see the relative **costs of holding either too much or too little inventory**. If demand were less than expected, we would incur extra inventories and the cost of holding them. If demand were greater than expected, we would incur backorder or shortage costs and the possible opportunity costs of lost sales.

Finally, in Figures (e) and (f), we have included two cost items associated with changes in output and employment levels. When output rates are changed, some costs are incurred in **reorganizing and rebalancing for the new level and in balancing labor**.

Many costs affected by aggregate and scheduling decisions are **difficult to measure** and are not segregated in **accounting records**. Costs associated with public relations and public image are not measurable. However, all the **costs are real** and bear on aggregate planning decisions.

Aggregate Planning Guidelines

The guidelines for Aggregate planning are presented below which will be discussed in detail.

1. Determine corporate policy regarding controllable variables.
2. Use a good forecast as a basis for planning.
3. Plan in appropriate units of capacity.
4. Maintain as stable a workforce as is practical.
5. Maintain needed control over inventories.
6. Maintain flexibility to change.
7. Respond to demand in a controlled manner.
8. Evaluate planning on a regular basis.

Corporate Planning Policy. All aggregate planning activities should rest firmly upon underlying business plan or the corporate objectives, for they direct organization activities and dictate items of vital importance to employees, such as whether they will have steady work or will be laid off and about the inventory policies.

Forecast as a basis for Planning. A good forecast of demand is the basis for aggregate planning and serves as a target to guide production activities. Forecast **controls and validity checks** should be constantly maintained to justify faith in the system.

Appropriate Units of Capacity. Plant capacity is relatively a fixed asset which is often not fully utilized. Many individual equipment capacities are not always balanced, thus limiting the output of the system. By taking all these things into consideration, aggregate planning should be done in such a way that plant capacity is **optimally** utilized. Also, the aggregate plans themselves should be expressed in **homogenous units of production** like labor-hours of production time, or other **units that are common or manageable**, rather than in monetary units.

Work-force Stability. This has become an increasingly important goal as firms has begun to accept a greater responsibility for their role in society, technically called as '**Corporate Social Responsibility**'. Employees give life to an organization, dedicate their work efforts to it, and are deserving of a just share of the benefits and the security it can provide. If workers are hired to satisfy a seasonal or peak demand, they should be made aware of the temporary nature of their employment before being engaged.

Effective Control over Inventories. Control over inventories is necessary to effectively use them. In other words, **specifying the aggregate levels** of raw materials, in-process, and finished goods inventory is essential. One of the best ways to exercise control is to have the **information about the real time** inventory levels.

Flexibility to Change. In the business realm change is inevitable. Aggregate plan should be done in such a way that it should support a **fast reaction** to the change with **little disruption to the plant**. Subcontracting is one way of shifting fluctuations to the external environment. Internally, inventory fluctuations generally cause less disruption than does employee turnover.

Controlled Response to Demand. The demand fluctuations should **not be permitted** to generate similar fluctuation in the production rates at a manufacturing plant. **Simulation studies** have revealed that production distribution systems that involve factory, distributor, and retailer inventories can have substantial **lag and pipeline effects**. A 10% increase in retail sales followed by normal inventory adjustments, can appear as a 40% increase by the time the demand information gets back to the factory.

Too rapid a response to demand, and overcorrection, can **amplify** demand fluctuations. Operation managers must guard against such effects by developing a **good information base**, assisting wholesalers and retailers with inventory control and production information, and **making a controlled, or modified, adjustment to demand**.

Evaluation of Planning Adequacy. Planning efforts are of no value unless the plans are implemented and do the job they are designed for. **Control** should be built into the aggregate planning system so that **actual levels of activity are measured**, the data are fed back to production control in a timely and accurate manner, comparisons are made of actual and planned levels, and corrections are authorized and made.

Aggregate Planning Strategies

Several short-term capacity adjustments can be used to absorb monthly fluctuations in demand. Common in make-to-stock organizations are **three such adjustments**: *work force size, work force utilization*, and *inventory size*. Any one of these can be varied to meet varying demand without varying the other two (thus they can be called **pure strategies**). Usually, however, some combination of the three is **better than just one**. In addition, manufacturers **often use** subcontractors, rented or leased equipment, and other external resources for responding to periods of heavy demand. Let us now focus on these three pure strategies.

Strategy 1: Varying the number of productive employees in response to varying output requirements

From historical data, management can estimate the average productivity per employee and thus determine the number of employees needed to meet each months output requirement. When required monthly output declines, employees can be laid off. As it increases, the workforce can be increased accordingly.

Several disadvantages of this strategy are obvious. The wide swings in employment levels mean very high hiring and layoff costs. Also, indirect costs of training new employees and lowered employee morale during periods of layoff are common. In addition, required work skills may not be readily available when they are needed. Lead times necessary to hire and train employees must be accounted for in the planning horizon. Furthermore, community reaction to such a strategy may be negative. Finally, this strategy is not feasible for companies constrained by guaranteed wage and other hiring and layoff agreements with unions.

Strategy 2: Maintain a constant workforce size but vary the utilization of the work force.

Suppose for example, we chose the strategy of employing certain fixed number of workers per month throughout the year. During the lean months (i.e. during the months of low demand), the work force would be scheduled to produce only the amount forecasted, resulting in some **idle working hours**. During high demand months, overtime operations would be needed to meet demand. The work force would then be intensely utilized during some months and underutilized during other months.

A big advantage of this strategy is that it avoids the hiring and layoff costs associated with strategy 1. But other costs are incurred instead. Overtime, for example, can be very expensive, commonly at least 50 percent higher than regular time wages. Furthermore, there both are legal and behavioural limits on overtime. When employees work a lot of overtime, they tend to become inefficient, and job-related accidents happen more often. Idle time also has some subtle drawbacks. During slack periods, employee morale can diminish, especially if the idle time is perceived to be precursor of layoffs.

The aggregate plan following the strategies 1 and 2, in which the output closely follows the demand is called as a "**Variable output rate plan or Chase plan**". The predominant costs in this plan are labor hiring and layoff costs and overtime working costs and also there will be costs due to productivity effects.

Strategy 3: Vary the size of inventory in response to varying demand.

Finished goods inventories in make-to-stock companies can be used as a **cushion against** fluctuating demand. Select a fixed number of employees in such a way that there is little **or no overtime or idle time** and this can be maintained throughout the planning horizon. Producing at a constant rate, output will exceed demand during slack demand periods, and finished goods inventories will accumulate. During peak periods, when demand is greater than capacity, the demand can be supplied from inventory. This planning strategy results in fluctuating inventory levels throughout the planning horizon.

The comparative advantages of this strategy are obvious: stable employment, no idle time, and no over time. Coming to disadvantages, first, inventories of finished goods and other supporting inventories are not cost free. Inventories tie up working **capital** that could otherwise be earning a return on investment. Materials handling costs, storage space requirements, risk of damage and obsolescence, clerical efforts, and taxes all **increase with larger inventories**. Backorders can also be costly. Customers may not be willing to tolerate **backordering**, particularly if alternative sources of supply are available; sales may be lost, and the customer ill will may decrease future sales as well. In short, there are costs for carrying too much or too little inventory.

The aggregate plan following the strategy 3 which is calling for a constant rate of output for all time periods of production is called "**Level/Constant output rate plan**". The predominant costs in this plan are inventory costs and backordering costs.

In order to avoid high inventory related and changes in output rates costs in Level plan and Chase plan, there comes an "**Intermediate/Hybrid Plan"**, that changes output rates only **occasionally** instead of every month.

Comparing the plans. The three plans are evaluated on the **basis of total cost** for the planning horizon. The level output plan has high inventory costs and no overtime or rate change costs. The chase plan has negligible inventory costs, but high production rate change costs. However, the **intermediate plan** incurs **substantial costs** of inventories and rate changes but has **the lowest total cost**. This plan reflects a **mixed strategy**, using moderate (not extreme) amounts of inventory and output rate changes to absorb demand fluctuations. Hence, for this reason aggregate planning process is sometimes called **production smoothing**.

MASTER PRODUCTION SCHEDULE

The **next step** in the **planning process** after aggregate planning is Master Production Scheduling (MPS), which translates the aggregate plan into production schedules for individual products. As contrasted with aggregate plans, the master schedule or MPS is more **detailed**: it deals with individual products (not just product groups) and when they will be produced **week-by-week**. The process of translating aggregate plans into plans for individual products is called *disaggregation,* which has **no formal procedure** unto it, but has only **trial and error approaches**. Using **forecasts** of individual product demands, **trial amounts** of each product are scheduled week by week. The resulting weekly totals of output are then compared against aggregate requirements, checked for their capacity feasibility, and revised accordingly.

Functions of the Master Schedule/ MPS

The MPS formalises the production plan and converts it into specific material and capacity requirements. Labour, material, and equipment **needs for** each job must then be assessed. Thus the MPS **drives the entire production and inventory system** by setting specific production goals and **responding to feedback** from all downstream operations. Some key functions of the MPS are listed below.

1. Translate aggregate plans into specific end items.
2. Evaluate alternative schedules.
3. Generate material requirements.
4. Generate capacity requirements
5. Facilitate information processing
6. Maintain valid priorities
7. Effectively utilize capacity.

Translate aggregate plans. The aggregate plan sets a level of operations that roughly balances market demands with the material, labour, and equipment capabilities of the firm. The master schedule (MPS) translates this plan into specific numbers of end items to be produced in specific time periods. Products are grouped into lot sizes that are economical to produce and realistically load (but not over load and under load) the firms facilities. The MPS is thus a manufacturing plan of what the firm actually intends to produce (and not a forecast of what it hopes to sell).

Evaluate alternative schedules. MPS is a trial-and-error, work and rework activity. Many MPS software's have simulation capabilities that enable planners to "trial fit" alternative production schedules. Detailed material and capacity requirements are then derived, and the planner can see exactly what lead times and delivery schedules would result.

Generate material requirements. The MPS is the prime input for the material requirements planning (MRP) system. MPS signals the MRP system to purchase or produce the necessary components in sufficient time to meet the final assembly dates specified.

Generate capacity requirements. Capacity needs stem directly from material and job requirements, which in turn are established by the MPS. MPS is thus a prerequisite capacity planning. The MPS should reflect an economical usage of labour and equipment capacities. When capacity requirements are inappropriate (either too little or too much), the MPS should be revised.

Facilitate information processing. By controlling the workload on different workstations in the plant, the MPS determines when the deliveries will be made, both for make-to-stock and make-to-order items. MPS is also a key input for coordinating other management information such as marketing capabilities, financial resources (for carrying inventory), and personnel policies (for supplying labour).

Maintain valid priorities. Priorities can be absolute (relating to how far a job is behind or ahead of schedule), or they can be relative (that is, a rank in comparison with other jobs). In either case, they should reflect true needs if the supervisor and the worker are to have confidence in the system. This means that the due date or rank should correspond with the time the order is actually needed. Customers may change their orders, and materials are sometimes scrapped. When components are not actually needed or end items cannot be produced because of shortage of material, the MPS should be adjusted to reflect this change.

Effectively utilize capacity. By specifying end item requirements, the master schedule also establishes the load and the utilization for labour and equipment. To utilize capacity most effectively, the MPS may call for delaying some orders or build others ahead of demand.

Guidelines for MPS

Some guidelines for implementing and monitoring mater schedules are as follows.

1. Work from an aggregate production plan.
2. Schedule common modules when possible.
3. Load facilities realistically.
4. Release orders on a timely basis.
5. Monitor inventory levels closely.
6. Reschedule as required.

In addition to the aggregate plan, data should be available from forecasts and customer orders already received. By scheduling items in modules and/or at a point of high commonality of components or simply to say in part families, the immense problems of dealing with options are reduced. A realistic load on facilities means that the facilities are neither overloaded nor under loaded. Similarly, the timely release of orders to the production shop means offering a realistic delivery date that shop personnel can feel confident with. Close monitoring of inventory levels is necessary to avoid excess inventories on one hand and stock outs on the other. Rescheduling capability acknowledges that changes do occur and permits the scheduler to keep priorities valid and capacities effectively utilized. However, judgment must be exercised so that neither too many nor too few reschedules are permitted.

Assembly v/s Process industry scheduling

Manufacturing assembly activities typically begin with many raw materials and components that are combined into one or a few end items, such as a computer. As illustrated in Fig. a, master scheduling here starts with the few types of end items and works "upstream" to determine the raw material and component needs from the projected number of end items. Most computerized MRP systems are designed to accommodate this type of scheduling logic. Firms that produce large volumes of a few items often produce for stock, and *material availability* is frequently a major concern in these firms.

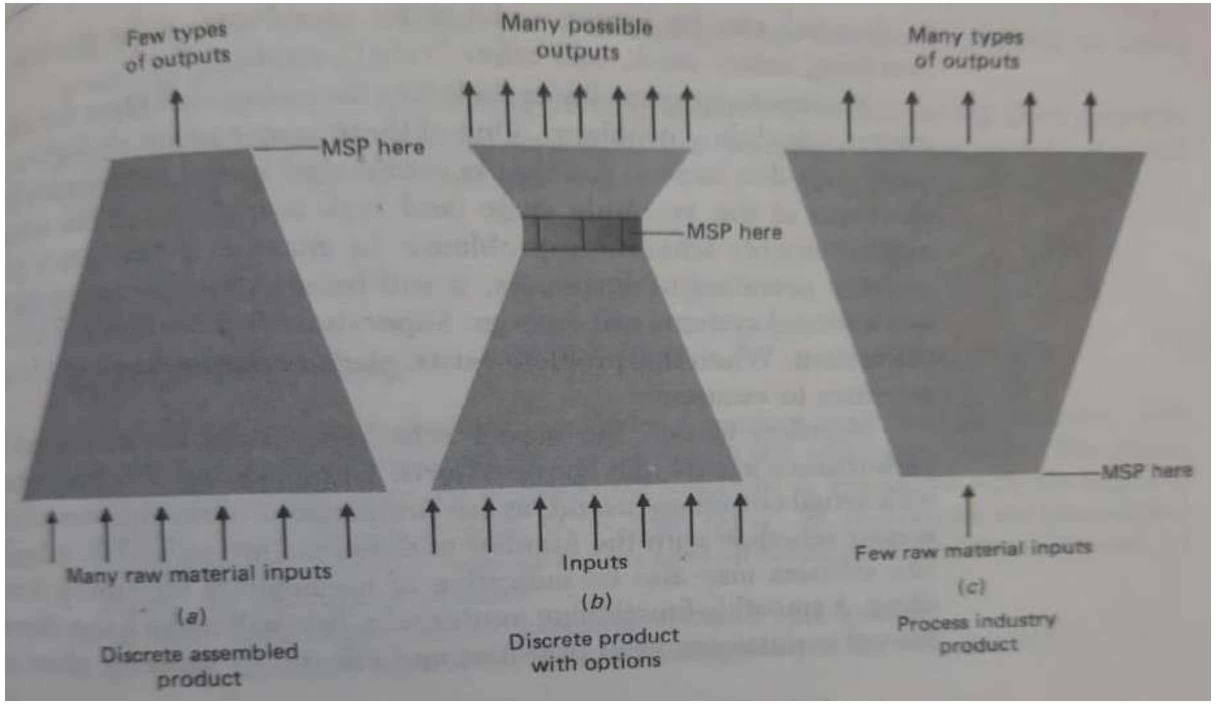
Process industry manufacturing is almost the reverse the assembly manufacturing. It begins with one or a few types of raw materials that are sorted, milled, or somehow processed into a multiple end-items and by-products, such as the many petroleum products that come from crude oil. Fig. c illustrates this. In this situation MPS begins at a raw material (input) level and must plan for the materials and capacities needed for the various categories of outputs. When processes have uncertain yields, such as in many food processing plants, the scheduling and control over inventories can be a challenge. *Capacity* to handle the variable levels of materials is a major concern in process industries.

Fig. b depicts an assemble-to-order (or) make-to-order situation where the master schedule item is a major subassembly, but not necessarily the finished product. This is the approach followed by the firms assembling a high volume of products that may offer options numbering in the thousands.

Note: Assemble to order is **a production scheduling strategy in which a retailer collects the raw materials needed to make a product in advance**. The product is assembled and completed only when a customer orders it. This is different from traditional manufacturing, where a finished product is built in advance of sale.

Example: A PC-maker that receives orders and then assembles **customizable computers using components like keyboards, monitors, and motherboards** is using an assemble-to-order strategy. Dell, Ferrari, etc.

Figure: Assembly Vs. Process industry scheduling



Difference between Master Scheduling and Shop Floor Scheduling

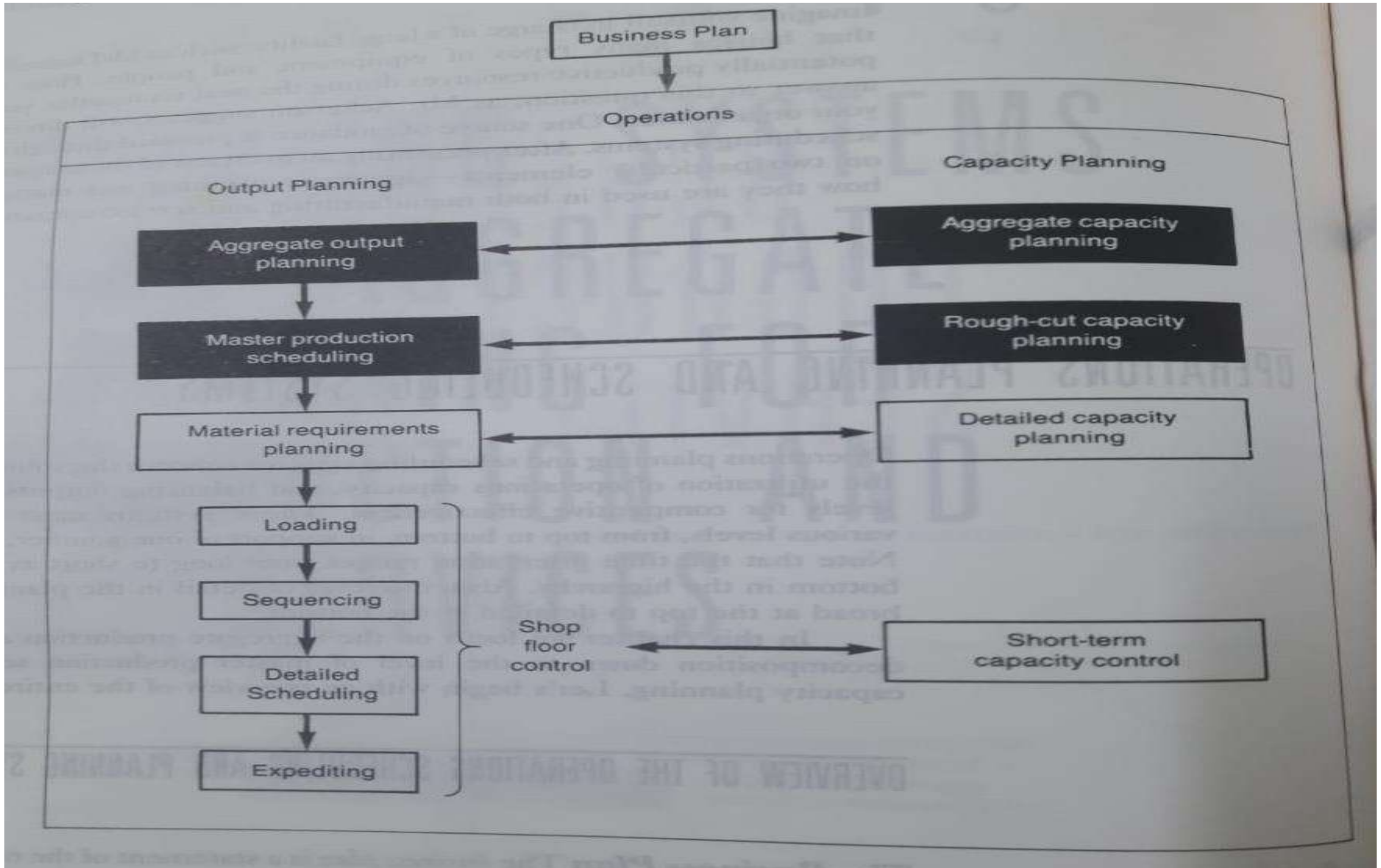


FIGURE 10.1 The operations planning and scheduling system

in the operations planning and scheduling system, Master production schedule comes right after the Aggregate planning. Unlike the aggregate planning talking about the product group, the purpose of MPS is to meet the demand for **individual** products in that product group. This more detailed level of planning ***disaggregates*** the product groups into individual products and indicates **when t**hey will be produced. In other words, it is a schedule showing **week by week** how many of each product must be produced according to customer orders and demand forecasts.

Coming to Detailed scheduling which can also be called as shop floor scheduling or operations scheduling, it is part of the shop floor control which is positioned following the Material Requirement Planning (MRP). In detailed scheduling, the starting times and ending times for processing of each job/activity on a given machine/work centre is decided. By estimating how long each job will take to complete and when it is due, schedulers can establish start and finish dates and develop the detailed schedule. Detailed scheduling is carried out at day to day level, While MPS is on week by week basis.

Operations Management

Course Teacher

Dr. Sricharan

Mechanical Engineering Department

S. R. K. R. Engineering College, Bhimavaram

III/IV 2 Semester 2022-2023

UNIT 4

Inventory Control

- Inventory defined; Why inventories?
- Manufacturing v/s Distribution Inventory
- Multistage Inventory v/s Multiechelon Inventory
- Inventory systems:

  Q/R Inventory system,

  Periodic Inventory system, and

  JIT Inventory system
- Inventory costs
- Problems on basic EOQ model
- Selective inventory control techniques:

  ABC analysis and

  VED analysis.

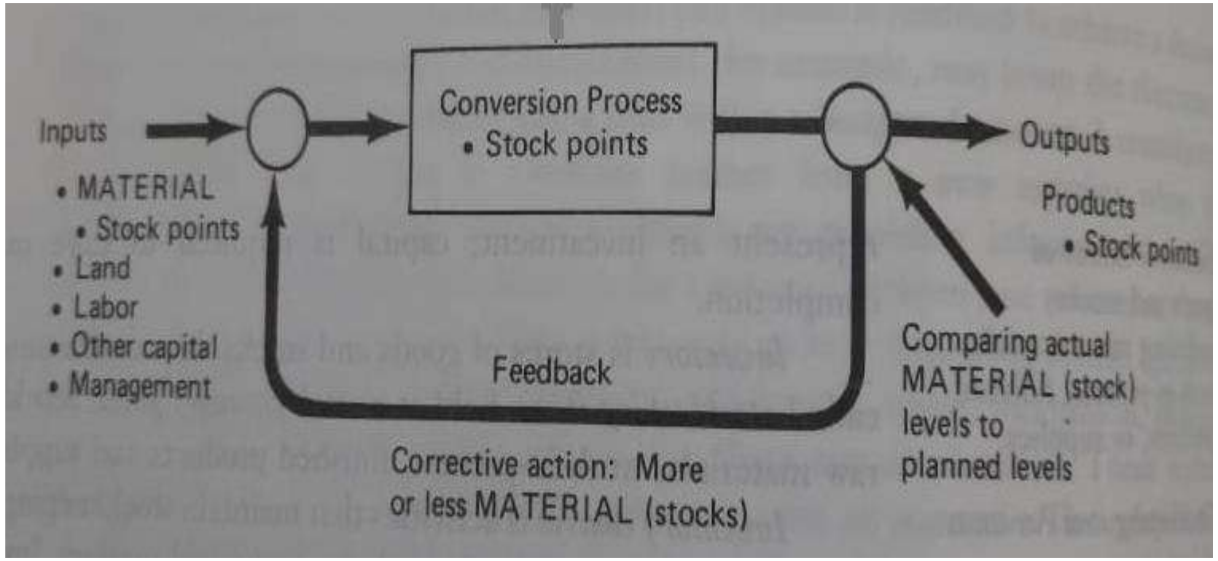
UNIT 4 – FUNDAMENTALS OF INVENTORY CONTROL

Inventory Defined

Inventory is **stores of goods and stocks**. In manufacturing, items in inventory are called **stock keeping items**, held at a **stock (storage)** point. Stock keeping items usually are raw materials, components, work-in-process, finished goods and supplies.

Inventory control is activities that **maintain** stock keeping items at **desired levels**. In ***manufacturing***, since the focus is on a physical product, inventory control focuses on **materials control**. In the ***service sector***, since the focus is on a service, which is often consumed as generated, inventory control focuses less on materials and more on **supplies**, like for example, beds and medical equipment in the case of **hospitals**.

If we look at the production/operations management model or transformation model (shown in the adjacent Figure) which is focusing on conversion of inputs into outputs of goods or services, there are stock points at the **input** (raw material), **conversion** (work-in-process), and **output** (finished product) stages.



Dependent Vs Independent Demand

Demand for a product or service is termed **independent** when it occurs independently of demand for any product or service. Conversely, when demand for one product is linked to demand for another product, the demand is termed **dependent**. Only independent demand needs **forecasting**; dependent demand can be **derived** from the independent demand to which it is linked.

Dependent demand inventory consists of raw materials, components, and subassemblies that are used in the production of parent or end items. For example, the demand for keyboards depends on the demand for the parent item, computers. Thus, the **manufacturing inventory** (the inventory used for manufacturing of final item) is largely dependent and predictable.

Independent demand inventory consists of the finished products, service parts and other items whose demand arises more directly from the **uncertain market environment**. These **distribution inventories** often have an independent and highly uncertain demand.

<u>**Note:**</u> This unit is primarily concerned with the independent demand items, i.e., distribution inventories.

Manufacturing Versus Distribution Inventory

The manufacturing inventories are the raw materials, components, and subassemblies maintained to support planned manufacturing operations. These materials and components are classified as dependent demand because the number required depends upon the number of end items scheduled for production. Once the production plan has been formulated, the requirements for the components that are assembled into finished products can be calculated (for example, by an MRP system).

In manufacturing inventories, then, the **timing of the arrival** of materials and components is often more important than having an extra stock of those materials on hand. This is not to suggest that some reserve of these materials and components should not be maintained for scrap losses, breakdowns and so on. However, for the most part, manufacturing requirements are predictable.

Distribution inventories are the finished goods flowing from the manufacturing process, which are classified as independent demand. Independent demand can **occur randomly and is not as predictable**, so having a **reserve stock of inventory** on hand to compensate for **uncertainties** is usually desirable.

Multistage Inventories Vs Multiechelon Inventories

Multistage inventories. When parts (which eventually become finished goods) are stocked at more than one point in the sequential production process, there are *multistage inventories*. These partially finished parts waiting for completion and eventual sales are called as *work in process/ work in progress/ goods in process/ in process inventories* and if they are stocked at multiple stages in the production process it is called as Multistage inventories.

Multiechelon inventories. As shown in the adjacent figure, these are inventories of products at the various levels or echelons – factory, warehouse, retailer, and customer – in a distribution system.

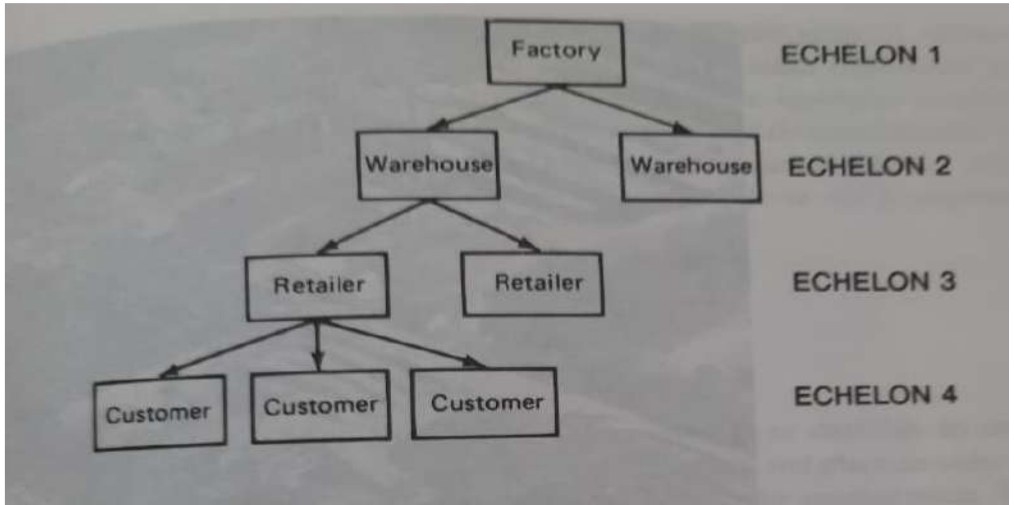


FIGURE Multiechelon inventory systems

Why Inventories? (or) What is the purpose of Inventories?

The **fundamental/primary** reason for carrying inventories is that *it is **physically** impossible and **economically** impractical for each stock item to arrive exactly **where** it is needed and exactly **when** it is needed*. Even if it were possible for a supplier to deliver raw materials every few hours, for example, it could still be prohibitively expensive. The manufacturer must therefore keep extra supplies of raw material inventory to use when they are needed in the conversion process. The other **secondary reasons** for carrying/holding inventories are as explained below:

- When demand is unusually variable i.e. during **immediate and seasonal demands**, some buffer is needed against prospects of high stockout costs because of stockout situations. Inventory can be used to “buffer” against such uncertainties. Likewise, **lead time,** the time between ordering and receiving goods, is not always constant. Buffer stocks can be used to protect against stockouts from uncertain demand during lead time.
- Inventories can also help to **level or smoothen the production**. In the **Level aggregate planning** we can examine that inventory can be built during slack demand periods and used in peak demand periods. Thus high costs of production rate and workforce level changes can be avoided.
- Inventories are also useful when they ***decouple*** operations – that is, when they break operations apart so that one operation’s supply is independent of another’s supply. This decoupling serves **two purposes**. **First**, decoupled operations means that **breakdowns**, material shortages, or other production fluctuations at one stage of operation **do not cause later** stages of operation to shut down. A **second** purpose of decoupling through inventories is that one organizational unit can **schedule its operations independently** of another. In automobile manufacturing, for example engine buildup can be scheduled separately from seat assembly, and each can be decoupled from final automobile assembly operations through in process inventories.
- With bulk purchases, **quantity discounts** can be arranged; thus a cost advantage of materials inventories is realized. Suppliers of materials that achieve economies of scale by **producing or transporting** large volumes often offer quantity discounts.

- Inventories provide a means of hedging against future price and delivery uncertainties, such as price increases, inflation, and strikes.

The Operating Doctrine

Operations managers must make **two** inventory policy decisions: ***when*** to reorder stock and ***how much*** stock to reorder. **These decisions** are referred to as the inventory control ***operating doctrine***.

The time to reorder is called the ***reorder point***. Here the system signal is usually a predetermined inventory level which tells clerical or other responsible personnel when it is time to reorder stock. The amount that should be reordered is called ***order quantity***. *Both the inventory level that signals the reorder and the order quantity are economic decisions at the heart of the operations managers inventory control function*. Although the manager may not actually operate the control system, he or she is responsible for setting the operating doctrine.

Inventory Systems/ Inventory Control Systems

Inventory control systems are the ordering and monitoring techniques used to control the quantity and timing of inventory transactions. The **traditional** inventory control systems are classified as either perpetual (continuously monitored) or periodic and numerous **combinations of them**. In addition, many **broad based scheduling systems** incorporate **inventory control activities** as an **integral part** of the larger systems.

The Japanese have introduced the world to just-in-time (JIT) inventory management systems with Kanban material movement subsystems in it. And the computerized MRP systems, developed largely in the USA, are very highly integrated production and inventory control systems.

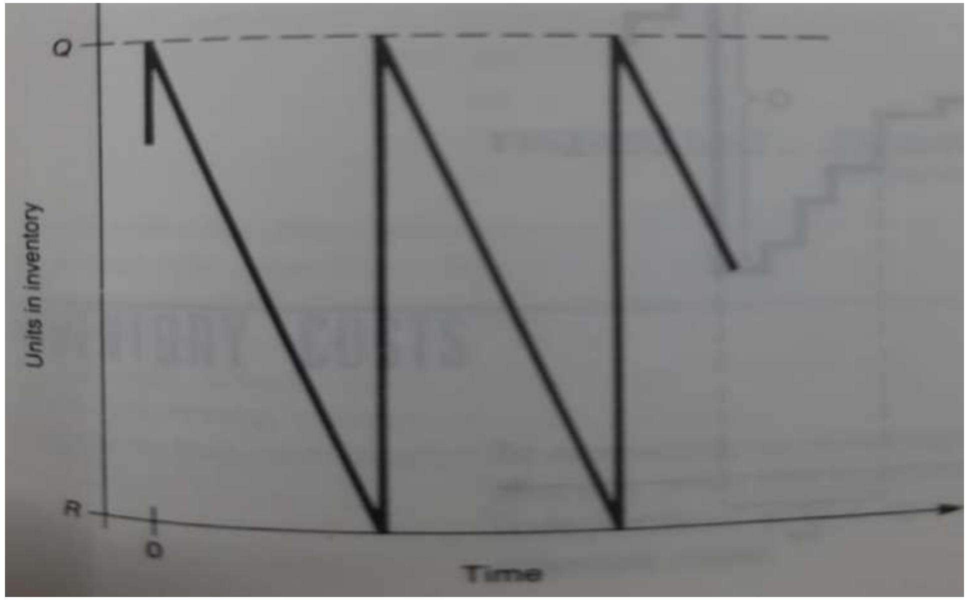
The perpetual and periodic systems, by themselves, are essentially only *order launching* techniques. Nevertheless, they are still widely used as a basis for releasing orders because they answer the basic questions of *how much to order* and *when*. This is often satisfactory for **distribution inventories** but is usually unsatisfactory for manufacturing inventories. MRP system is used for manufacturing inventories, which we will be discussing in next unit.

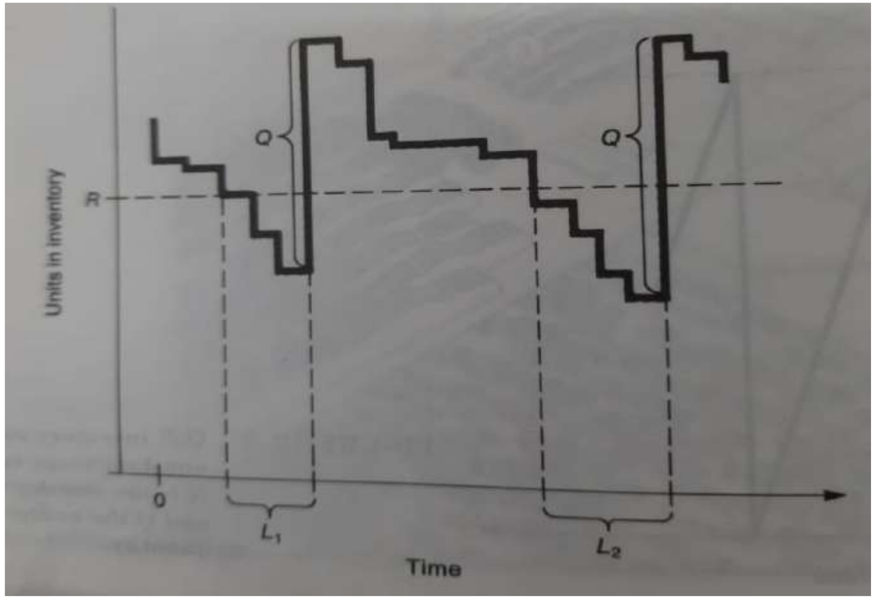
Q/R (or) Perpetual (or) Fixed Order-Quantity Inventory System

One practical way to establish an inventory system is to keep **perpetual record of every item** issued from inventory and place an order for more stock when inventories dwindle to a predetermined level, the **reorder point (R)**. The **reorder quantity (Q)**, also called the economic order quantity (EOQ), is fixed in size (volume), size having been predetermined. The following figures illustrate two such Q/R inventory systems. In the first figure, **demand for inventories**, also called **usage rate** is known and constant. Replenishment inventories are assumed to be received at the stock point the moment they have been ordered. Hence, the **procurement lead time is zero**. In a simple case like this, there would be no need to carry buffer stocks: Delivery is instantaneous, and the demand for inventory item is known for certain. Thus R can be set at zero units.

The inventory situation is slightly more complex for the system shown in second figure. Here the **usage rate is variable**; we do not know in advance how rapidly inventory will be depleted. Also, the **lead time varies too**. As in the above case, both R and Q are constant. However, since both the usage rate and the lead time are varying, the **time interval between orders varies**.

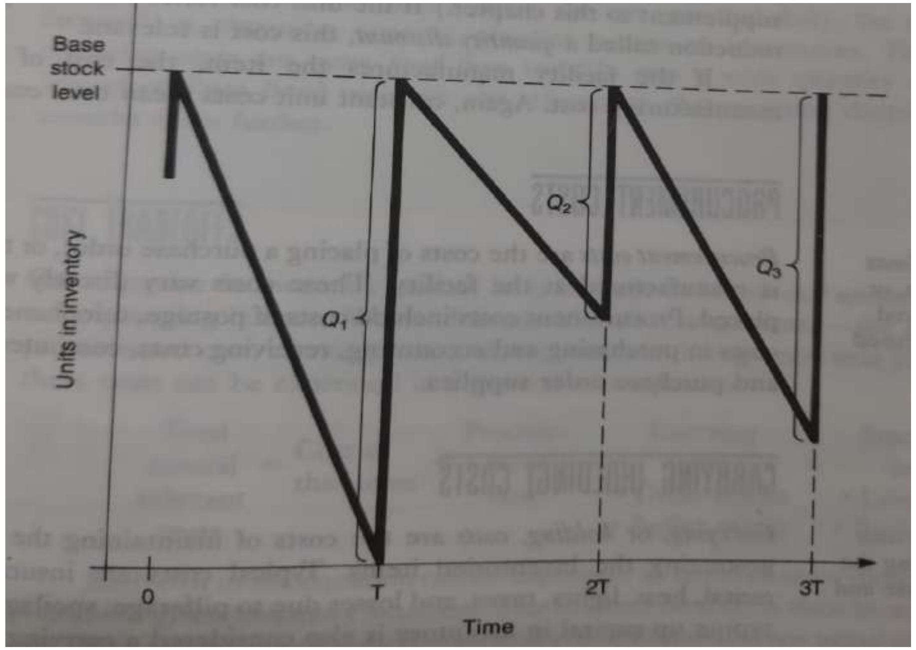
This system requires continuous monitoring of inventory levels, which can easily be done if the system is **computerized**. Because of this, it is often used for inventories that have **large, unexpected fluctuations in demand**.





Periodic/ Fixed Order-Interval/ Fixed Order-Period Inventory System

Another practical inventory control method is to count inventories at **set time intervals, periodically** (such as weekly or monthly). With this method, the **order quantity** will be whatever is needed to bring the amount of inventory back up to some preestablished ***base stock level***. As the following Figure illustrates, the level of inventory is examined at times, T, 2T, 3T and orders are placed for quantities Q1, Q2, Q3. The base stock level and the time T between the orders is set by the operations manager. Although the following figure shows constant demand within any one review period and zero lead time, these conditions could be **relaxed and still** allow the periodic inventory system concepts to be retained. This system does not, however, require continuous monitoring, and it is especially useful for purposes that call for a **continuous use of material**.



Similarities between these two systems based on Operations Doctrine

EOQ in the Q/R system and the base stock levels in the periodic system determine **how much to order**; reorder point in the Q/R system and time between the orders in the periodic system determine **when to order**.

JIT Inventory System

Just-in-time (JIT) is a manufacturing philosophy developed in Japan for the **high volume production of discrete units** (such as Toyota Automobiles). It is sometimes described as an inventory control system because of its inherent tight control over inventory, rather restriction over inventory. In JIT systems, inventory viewed as **waste**. It just sits there tying up funds and taking up space (a problem which the Japanese take seriously). Instead of using inventory as a protection against emergencies, JIT systems "cut it to the bone" so as to **expose the scheduling, materials or other problems** in the system – which are then attacked and corrected. In the original JIT systems, inventory is controlled by a **visual (Kanban) system** that virtually assures that **work-in-process** will be kept to a minimum.

The major tenet in this system is to avoid holding ay unnecessary inventory. **Instead**, the firms rely upon the careful scheduling of work, on-time delivery of (zero-defect) supplies, and skilled workers who are capable of handling any problems that may arise during production (such as shortages and breakdowns).

The absence of unnecessary inventory forces JIT system to become very **flexible to change** – for example, to be able to produce a different part or model on a moment's notice. Setup and "model change-over" times in JIT plants are typically reduced from hours to minutes. (This in turn can save millions of dollars in idle time costs.) As is evident, teamwork and close cooperation of everyone is vital. Suppliers even cooperate to deliver parts several times per day.

Inventory Costs

In operating an inventory system managers should consider only those costs that vary directly with the operating doctrine in deciding when and how much to reorder; costs independent of the operating doctrine are irrelevant. Basically, all the inventory carrying costs are classified into three categories:

1. Inventory carrying or stock holding costs
2. Procurement costs (for bought outs) or Setup costs (for made ins) and
3. Shortage costs (due to dis-service to the customers)

Carrying/Holding Costs

Carrying or holding costs are the costs of maintaining the inventory warehouse and protecting the inventoried items. They vary directly with the size of the inventory as well as the time the item is held in the sock. Various components of these costs are:

- *Costs of money or capital tied up in inventories*. This is by far, the most important component. Money borrowed from banks may cost the interest of about 18%. And, how much the organization would have earned, had the capital been invested in an alternative project such as developing a new product, etc. it is generally taken somewhere around 15% to 20% of the value of inventories.

- *Cost of storage space.* This consists of rent for space and also include heating, lighting and other atmospheric control expenses. Typical values may vary from 1 to 3%.
- *Depreciation or deterioration costs.* They are especially important for fashion items or items undergoing chemical changes during shortage. Fragile items such as crockery are liable to damage, breakage, etc. o.2% to 1% of the stock value may be lost due to damage and deterioration.
- *Pilferage costs.* It depends upon the nature of the item. Valuables such as gun metal bushes and expensive tools may be more tempting, while there is hardly any possibility of heavy casting or forging being stolen. Pilferage cost may be taken as 1% of the stock value.
- *Obsolescence cost.* It depends upon the nature of the item in stock. Electronic and computer components are likely to be fast outdated. These costs may be taken as 5% of the stock value.
- *Handling costs.* These include all costs associated with movement of stock, such as cost of labour, overhead cranes, and other machinery used for this purpose.
- *Record-keeping and administrative costs.* There is no use of keeping stock unless one can easily know whether or not the required item is in stock. This signifies the need of keeping funds for record-keeping and necessary administration.
- *Taxes and Insurance.* Most organizations have insurance cover and this may cost 1 to 2% of the invested capital.

Procurement costs or Setup costs

These include the fixed cost associated with placing a purchase order or setting up a machinery before starting production if the item is manufactured at the facility. Also called *order costs or replenishment costs*, they are assumed to be independent of the quantity ordered or produced but directly proportional to the number of orders placed. These costs include costs of postage, telephone calls to vendors, labor costs in purchasing and accounting, follow up costs, receiving the goods costs, quality control costs, etc.

Shortage costs or Stock-out costs

These costs are associated with either a delay in meeting demands (backorder or backlog case) or the inability to meet it at all (stock-out case). In case the unfilled demand can be filled at a later stage (backlog case), these costs are proportional to quantity that is short as well as the delay time. This include loss of good will and money paid to reorder goods and notify customers when goods arrive. In case the unfilled demand is lost, these costs become proportional to only the quantity that is short. However, this results in cancelled orders, lost sales, profit and even the business itself.

Selective inventory management techniques

The inventory of an industrial organization consists of hundreds and thousands of items having widely varying **costs, usage and lead time** together with procurement and/or technical **problems**. It is neither desirable nor possible to exercise the same degree of control over all these items. Also, the **time and record keeping activities** required to control thousands of materials cost a good deal of money. For example, for some items of low unit cost, such as bolts and paper clips, bearing the expense of exacting control is not required, whereas for other items it is necessary. Hence, the management should pay more attention to those items whose **usage value** is high and less attention to those items having low usage value. The organization should, therefore, be **selective** in its approach towards inventory control and the techniques used are called selective inventory control techniques. Some of such selective inventory control techniques are **ABC Analysis** and **VED Analysis**.

ABC Analysis/Classification System

One scheme for classifying the materials is the ABC method, which is based on the **idea that** only a small percentage of materials represent high usage value. This **widely recognized characteristic** has led many firms to classify their material inventories into three groups, designated as A, B, and C based on their **usage values**. ABC (Always Better Control) analysis is also known as *'control by importance and exception'* and *'proportional value* analysis'.

It has been found that normal inventory items in most organizations show the following distribution patterns:

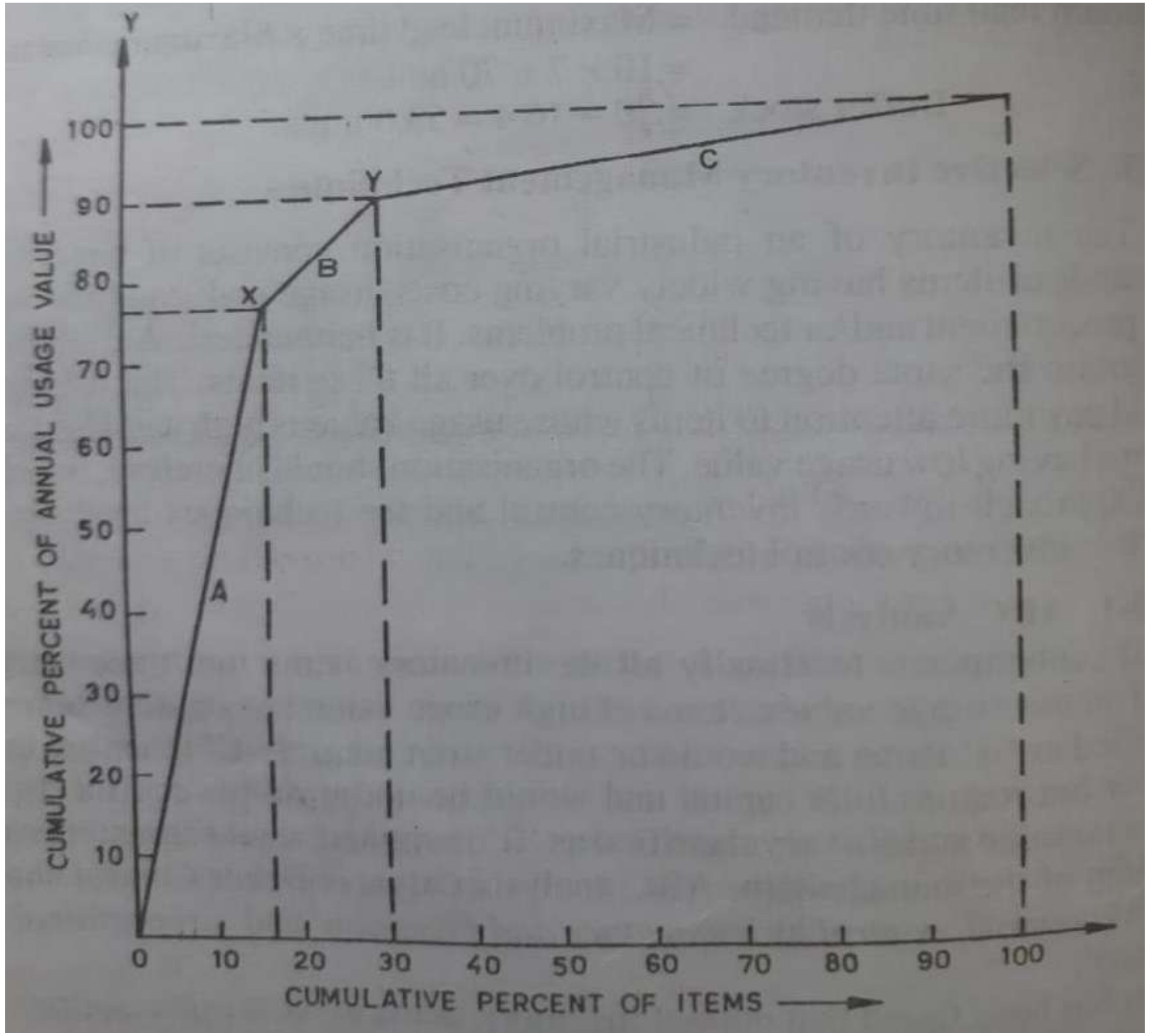
1. The A materials represent only 10 to 20 percent of materials in inventory and 70 to 80 percent of the annual usage value and would be under strict control.
2. The B materials represent 30 to 40 percent of materials in inventory and 15 to 20 percent of the annual usage value and would be under reasonable/normal control.
3. The C materials represent 40 to 50 percent of materials in inventory and only 5 to 10 percent of the annual usage value and would be under simple control.

<u>Steps for performing the ABC analysis</u>

In view of the several hundred and even thousand items stocked in most inventory situations, the ABC analysis may be carried out on a sample. Once a random sample has been obtained, the following steps may be performed for the ABC analysis:

1. Find the annual usage value of every item in the sample by multiplying the annual requirement by its unit cost.
2. Arrange these items in the descending order of usage value computed above.

3. Accumulate the total number of items and the usage value.
3. Convert the accumulated totals of number of items and usage values into percentage of the grand totals.
3. Plot the two percentages on the graph papers as shown in the following Figure.
3. Mark the cut-off points X and Y where the curve changes its slope. Dividing it into three segments A, B, and C. These segments for the sample are then generalized over the entire population of stock items.



The following Table summarizes the key characteristic of this system.

Groups	Quantity (% of items)	Value (% of Rupees)	Degree of Control	Types of Records	Safety Stock	Ordering Procedures
A items	10-20%	70-80%	Tight	Complete accurate	Low	Careful, accurate; frequent reviews
B items	30-40%	15-20%	Normal	Complete accurate	Moderate	Normal ordering; some expediting
C items	40-50%	5-10%	Simple	Simplified	Large	Order periodically; 1 to 2 year supply

Experience (as is indicated in the table) has shown that a small percentage of materials (10 to 20%) typically accounts for a major portion (70 to 80%) of the value of materials in the stock. This disproportion has led the firms to use the ABC system of classification, which enables them to have **closer control** over the **high value and critical items**. Thus, an organization would devote much time and effort in the control of 'A' items. Extra care will be taken for determining the minimum, maximum inventory levels and reorder level etc. of the 'A' items. 'A' items have high inventory carrying costs and should, therefore, be procured in smaller lots. 'C' items require very little capital and hence have low inventory carrying costs and should be brought in bigger lots so that there are fewer orders and hence lower acquisition cost. Although the ABC classification system is not precise, it is a useful way of focusing control and is widely used.

Advantages of ABC analysis

1. ABC analysis is a dynamic procedure and must be repeated at least when the product mix changes.
2. It helps in exercising selective control over the items by concentrating efforts in areas where it needed most. For instance, control over ‘C’ items may be relaxed even to the extent of dispensing with inventory records. For ‘A’ items the buffer stocks must be kept the absolute minimum and very careful attention is paid to their demand estimates, scheduling of deliveries, prompt, receipt, immediate inspection and rapid flow through the factory.
3. It provides a more sound cost perspective to the management and enables them to assign priorities in cost reduction program.
4. It avoids wastage of time and energy in making improvements in areas that yield only marginal benefits (class ‘C’ items).

VED Analysis

This analysis divides items into three categories in the **descending order of their criticality**. ‘V’ stands for *vital items* and their stock analysis requires more attention since out-of-stock situation would result in **stoppage of production**. Thus, ‘V’ items should always be sufficiently stocked to ensure smooth operation of the plant. ‘E’ denotes *essential items* which are necessary for the **efficient** running of the system but without which the system will **not fail**. Care should be taken to ensure that they remain always in stock. ‘D’ represents *desirable items*. They **do not immediately affect production** but they help to **increase efficiency and decrease fatigue**. As VED analysis categorizes the items on the basis of their **criticality**, it can be **used to** determine the stock levels of spare parts and special raw materials which are **scarce and difficult to procure**.

Operations Management

Course Teacher

Dr. Sricharan

Mechanical Engineering Department

S. R. K. R. Engineering College, Bhimavaram

III/IV 2 Semester 2022-2023

UNIT 5

Resource Requirement Planning

- MRP and CRP overview
- Objectives of MRP
- Inputs/Outputs to MRP System; MRP Logic
- Limitations and Advantages of MRP
- MRP II
- ERP
- Introduction to JIT manufacturing philosophy; Benefits

UNIT 5 – RESOURCE REQUIREMENT PLANNING

Overview: MRP and CRP

Suppose you were in charge of production at one of General Motor's automobile plants for the coming month. Your aggregate plan and master schedule have spelled out what models and how many to produce. And your inventory system can tell you what materials are on hand. So now comes the next step. Build the cars – just build the cars.

All of a sudden the pressure is on! A quick check reveals inventories of parts are **purposely low**. You have **neither the storage space** nor the **financial luxury** for stocking inventory that "might" be needed in a few weeks. How will you ever arrange to have the **right amount of** steel, windshields, and tyres available at the **right time**? Even if the steel is available, how can you **be sure your** numerous machine shops can grind out the door panels, engine blocks, etc. when you need them? One little shortage you are in trouble. Your mile long production shop could be shut down in 2 minutes – perhaps less.

***What are MRP and CRP*?** Companies that produce end products from purchased and/or manufactured components need a **systematic method of planning** for their material and capacity requirements.

Material requirements planning (MRP) is a technique for determining the **quantity and timing for the acquisition** of dependent demand items needed to satisfy master schedule requirements.

Capacity requirements planning (CRP) is a technique for determining what **personnel and equipment** capacities are needed to meet the **production objectives** embodied in the master schedule and the material requirements plan.

Together, MRP and CRP established specifically **what** materials and capacities are needed and **when** they are needed. Every big and small manufacturing companies should take full advantage of these techniques. Otherwise they simply could not survive in today's market.

Although MRP and CRP appear to be two different concepts, CRP activities are often assumed to be **included** within the concept of "**MRP System**". Beyond this MRP System, the term **"MRP II"** has been coined by **integrating** financial, accounting, personnel, engineering, and marketing **information** – **along with** the production planning and control activities of basic MRP systems. This broad based **coordination of various information systems** within the context of the corporate business plan has been labelled *manufacturing resource planning (MRP II)*. For many manufacturing firms, MRP II is the "heart" of their Corporate Management Information System.

What do MRP and CRP together accomplish? (OR) What are the objectives of MRP?

According to the president of a firm that supplies Caterpillar Tractor Company,

> MRP has been revolutionary here at our firm. Not only has it brought about new ways of doing the things, it also nearly produced a **revolution**! It is an incredibly **simple idea** and yet it is **very difficult** system to implement. The **benefit** to us has been significant in many tangible ways; productivity increases, reduced purchases, greater customer service, and more. But the greatest benefit, in my mind, is that MRP has brought us all together in a **common effort**. Because we involved everyone, it has become **everyone's system**. Because we educated everyone, employees in every area of the company understand our **dependency on each other**. And finally, because we communicate continually about our goals, performances, weaknesses, and strengths, we have together improved our product, our productivity, and our profitability.

But, MRP systems aren't all roses. They can be **difficult to implement** – and they can be **costly** (from thousands of dollars to over a million dollars for some firms). Nor are many systems wholly successful. Nevertheless, the benefits of successful installations are often remarkable. Hence, the Operations Managers adopt MRP to achieve these objectives:

1. ***Inventory reduction.*** MRP determines how many of a component are needed and when, in order to meet the master schedule. MRP enables the manager to procure that component **as it is needed**, thereby avoiding costs of excessive inventory.
2. ***Reduction in production and delivery lead time.*** MRP identifies materials and components quantities, timings, availabilities, and procurement and production actions required to meet delivery deadlines. **By coordinating** inventories, procurement, and production decisions, MRP helps avoid delays in production.
3. ***Realistic commitments.*** Realistic delivery promises can enhance customer satisfaction. By using MRP, production can give marketing timely information about **likely delivery times** to prospective customers.
4. ***Increased efficiency.*** MRP provides close **coordination among various work centers** as products progress through them. Consequently, production can proceed with **fewer indirect personnel**, such as material expeditors, and with **fewer unplanned interruptions** because MRP focuses on having all components available at appropriately scheduled times. The information provided by MRP encourages production efficiencies.

All of these benefits result mainly from the **philosophy of MRP systems**. Simply put, MRP systems are based on the philosophy that each raw material, part, and assembly needed in production should **arrive simultaneously at the right time** to produce the end items in the MPS. This philosophy results in **expediting** the materials that are going to be late and **slowing down** the delivery of materials that are going to be early. For example, if one material is going to be late and nothing can be done about it, the other materials needed to assemble the end item will not be needed until the one late material arrives. The MRP system **changes the due dates** of all the materials so that materials arrive simultaneously to assemble the end item.

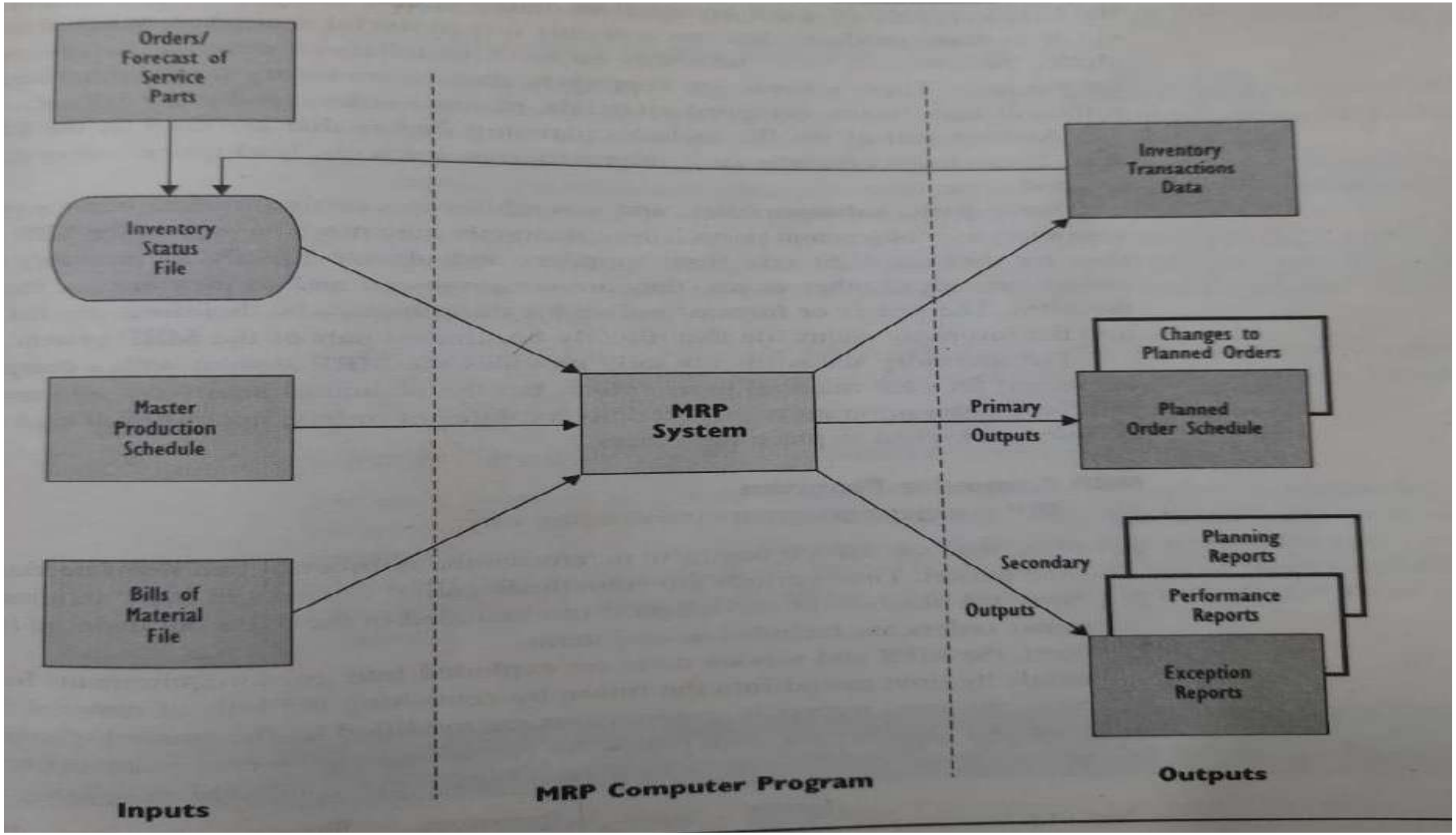
A **chief benefit** of this MRP systems philosophy is that production operations **work on parts that are really needed** on their due dates so that production capacity is being used only to support the MPS. This avoids **unnecessary expediting of parts** through the factory ahead of their due dates.

Elements/Components of MRP: Inputs, MRP Logic, and Outputs

The following Figure describes the operation of the MRP system. Three major sources of information **inputs** are mandatory in the MRP system: a master production schedule, an inventory status file, and a bill of materials file. The **MPS drives** the entire MRP system. It is **accepted as given**. The inventory status file and the bills of materials file supply additional information about products included in MPS. These inputs are fed into the MRP processing logic (computer program), which generates the outputs. The inventory transactions resulting from the MRP actions are put back into the inventory status file so that current inventory records are maintained. The planned order schedule and changes to planned orders are the primary outputs of MRP. Exception, performance, and planning reports are also generated for **management's use**, which are the secondary outputs. Let's examine each of these components in details.

INPUTS

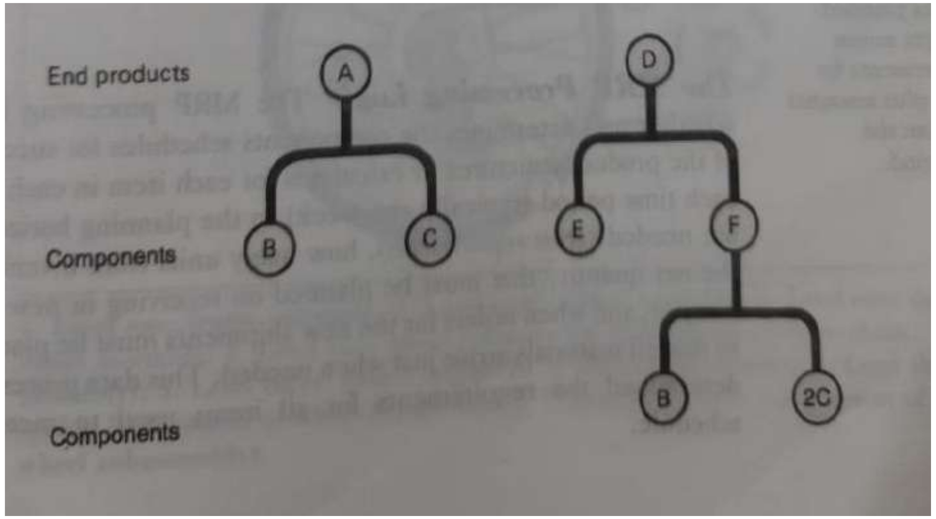
Master Production Schedule (MPS). The MPS is initially developed from firm's aggregate plan, customer orders in hand or from forecasts of demand before the MRP system begins to operate. Designed to meet market demand, the MPS identifies the quantity of each end item and when it needs to be produced during each future period in the production planning horizon. The MPS is an input to the MRP system and is accepted as it is. That is to say, MRP assumes that the MPS is produced within the production capacity constraints. Thus, the MRP **explodes the master schedule into material requirements**.


Orders/ Forecast of Service Parts
Inventory Status File
Master Production Schedule
Bills of Material File
MRP System
Inventory Transactions Data
Primary Outputs
Changes to Planned Orders
Planned Order Schedule
Secondary Outputs
Planning Reports
Performance Reports
Exception Reports
Inputs
MRP Computer Program
Outputs

Bill of Materials/ Bills of Material (BOM) file

A bill of material is a **list** of the **materials** and their **quantities** required to produce **one unit** of an end item or end product. Each product therefore has a bill of material. A bills of material file, or **product structure file** as it is sometimes called, is a complete list of all finished products, the quantity of each material in each product, and the **structure** (assemblies, subassemblies, parts, and raw materials and their relationships) of products. The **primary information** to MRP from the BOM is the ***product structure,*** An example of which is shown in the following figure. One unit of end product A requires one unit of each of components B and C. One unit of each product D requires one unit of component E and one unit of component F, which in turn requires one unit of component B and two units of components C.

In MRP terminology, A and D are *upper-level end items;* the components are *lower-level items.* Each item in the product structure is given a **unique identification number**. Subsequently, by knowing the master schedule for end items, MRP can **schedule and time-phase** the orders for the correct lower-level component items in the product structure.



Inventory Status File

The MRP system must retain an up-to-date file of the inventory status of each item in the product structure. This is a computerized file with a complete record of each item held in the inventory and all the inventory transactions, both actual and planned. This file contains the identification number, quantity on hand, safety stock level, quantity disbursed (allocated), and procurement lead time of every item.

The MRP Processing Logic/Computer Program

The MRP computer program operates this way:

1. First, with the **MPS** it begins to determine the number of end items needed in each time period (typically a week). Time periods are sometimes called ***buckets*** in MRP terminology.
2. Next, the numbers of **service parts** not included in the MPS but **deduced from customer orders** are included as end items.
3. Next, the MPS and service parts are exploded into **gross** requirements for all materials **by time period** into the future by **consulting the bill of materials file**.
4. Next, the gross materials requirements are modified by the amount of materials on hand and on order for each period by consulting the **inventory status file**. The **net requirements** of **each material for each bucket** are computed as follows:

$$\text{Net requirements} = \text{Gross requirements} - \left(\text{Inventory on hand} - \text{Safety stock} - \text{Inventory allocated to other uses} \right)$$

If the net requirements are greater than zero, orders for the material must be placed.

This procedure results in inventory transactions data (orders released, changes in orders, and so on), which are used to update the inventory status file, the primary output reports and secondary output reports.

Outputs of MRP

The outputs of MRP systems dynamically provide the **schedule of materials** for the future – amount of each material required in each time period to support the MPS. Two primary outputs result:

1. **Planned order schedule –** a plan of the quantity of each material to be ordered in each time period. This schedule is **used by purchasing** to place orders with suppliers and **by production** to order parts, subassemblies, or assemblies from upstream production departments. The planned orders becomes guide for future production at suppliers and for in-house production schedules.
2. **Change in planned orders –** modification of previous planned orders. Quantities of orders can be changed, order can be cancelled, or the orders can be delayed or advanced to different time periods through the updating process.

The secondary MRP outputs provide this information:

1. **Exception reports –** reports that flag items requiring management attention in order to provide the right quantity of materials in each time period. Typical exceptions noted are late orders, and excessive scrap.
2. **Performance reports –** reports that indicate how well the system is operating. Examples of performance measures utilized are inventory turns (how many times a company's inventory is replaced over a period of time), percentage of delivery promises kept, and stock out incidences.
3. **Planning reports –** reports to be used in future inventory planning activities. Examples of such planning information are inventory forecasts, purchase commitment reports, traces to demand sources, and long range material requirements planning.

Limitations and Advantages of MRP

The limitations of MRP system stem from the conditions that must be met in giving **accurate inputs** to the MRP logic. First, the bill of materials and inventory status information must be **computerized**; and a **valid master schedule** must be prepared. Another limitation has to do with **data integrity**. **Unreliable inventory and transactions data** from the shop floor can ruin a well-planned MRP system. **Training personnel** to keep accurate records is not an easy task, but it is critical to successful MRP implementation.

The **dynamic nature** of the MRP system is a **vital advantage**. It reacts well to changing conditions. **Changes** in the master schedule can affect not only the end item but also hundreds, even thousands, of components. Because the MRP system is computerized, management can make a new MRP **computer run** to revise production and procurement plans that react quickly to changes in customer demands as reflected in the master schedule.

Manufacturing Resource Planning (MRP II)

Historically, MRP systems typically were developed on a segregated basis, rather than as part of a highly **integrated information system**. However, companies are beginning to logically relate many of their information subsystems to the MRP system. Bills of material data, for example, can be shared with an engineering information system data base; order release and order receipts data can be shared by the order billing and accounts payable information systems; and inventory status data from MRP can be part of marketing or purchasing information systems. This type of information integration, in fact, is exactly the impetus for a new generation of manufacturing planning and control systems.

Manufacturing resource planning (MRP II, or “closed loop” MRP) is an integrated information system that steps beyond first-generation MRP to synchronize all aspects (not just manufacturing) of the business. The MRP II system (as shown in the below figure) coordinates sales, purchasing, manufacturing, finance, and engineering by adopting a focal production plan and by using one unified data base to plan and update the activities in all the systems.

One use of the MRP II system is to evaluate various business proposals. If, for example, the output of product X increases by 20% in weeks 15 to 20 and that of Y decreases by 15% in weeks 10 to 15, how would operations and profitability be affected? The system can simulate how purchases and, hence, accounts payable are affected, when deliveries to customers and accounts receivable occur, what capacity revisions are needed and, so on. The company-wide implications of the proposed change can be evaluated, and various departments can be coordinated according to a common purpose.

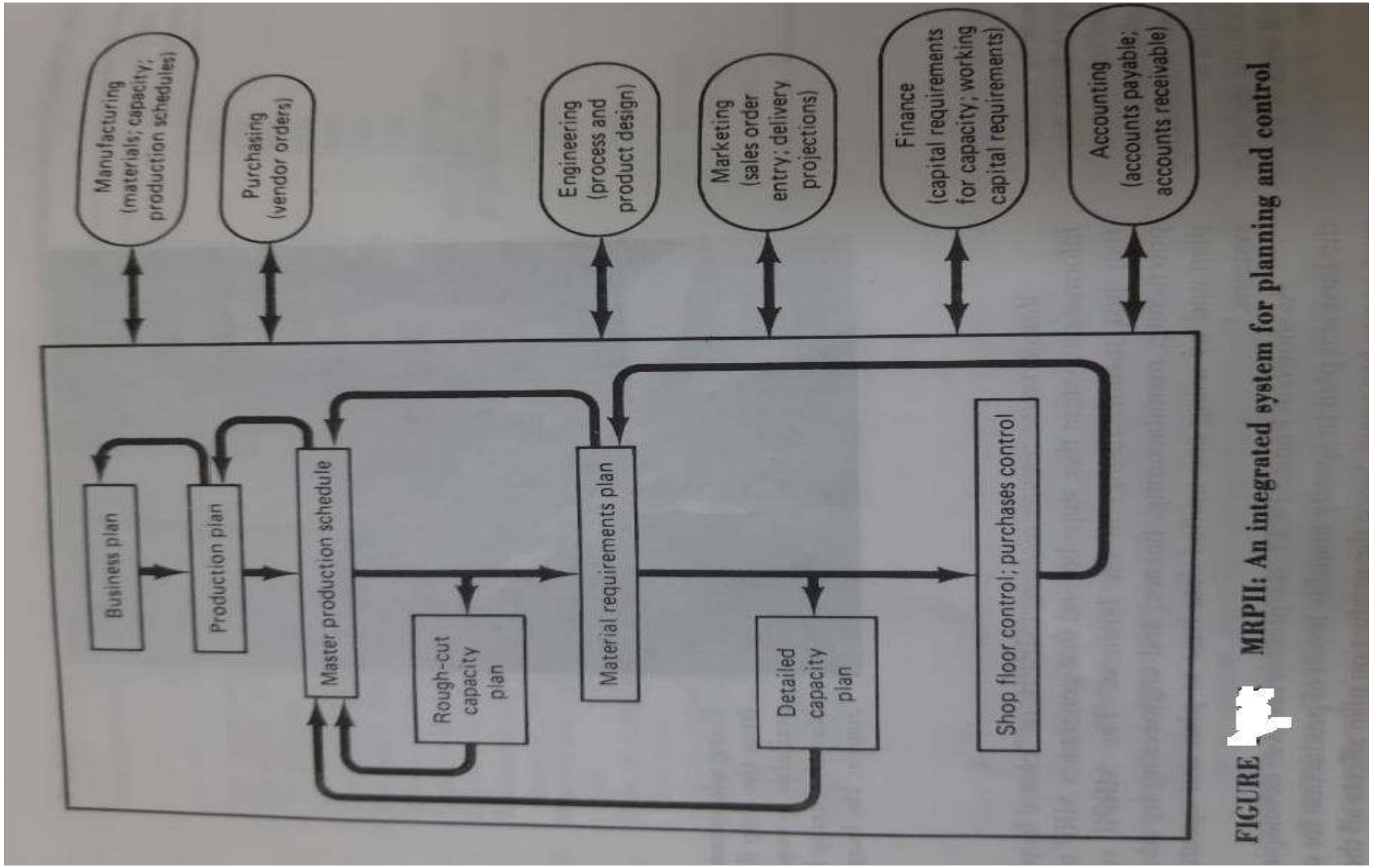


FIGURE MRPII: An integrated system for planning and control

Enterprise Resource Planning (ERP)

In the continuing evolutionary process of resource requirements planning systems, ERP is a next evolution from MRP II, which is even more comprehensive than MRP II is. ERP systems are the latest comprehensive software packages that companies are using to help automate a variety of business processes. These sophisticated software systems integrate most of the business functions in an organization. ERP systems automate manufacturing processes, organize accountant's books, streamline corporate departments like human resources, and even made the reengineering possible. The ERP software's such as *SAP, PeopleSoft,* and *Oracle* allows operations managers to obtain real time information about inventory levels, customer orders, current workloads, orders to vendors, and so on. This improved information allows for more timely, better, and much quicker decisions than ever before.

ERP systems consists of many software modules that can be separately purchased to help manage many different activities in different functional areas of a business. For example, SAP's R/3 software, the largest selling ERP software, offers modules for sales and distribution, financial accounting, work flow, industry solutions, materials management, production planning (including MRP and CRP), quality management, plant maintenance, and project systems. ERP systems require a major commitment and investment, often require companies to modify some of their processes to accommodate the software, and can take many years to implement.

The Just-In-Time (JIT) Manufacturing Philosophy

It is no longer good enough for firms to be high-quality and low-cost producers. To succeed today, they must also be first in getting products and services to customers fast. Quick response to market demands provides a powerful, sustainable competitive advantage. Indeed, time has emerged as a dominant dimension of global competition, fundamentally changing the way organizations compete. Firms like, Xerox, HP, Motorola, Honda, GE, Toyota, Sony, and Boeing are using JIT as a weapon in speeding market responsiveness. To compete in this new environment, the **order-to-delivery cycle** (the elapsed time between the moment that a customer places an order until the customer receives the order) must be drastically reduced. The following figure illustrates this important concept. JIT is the weapon of choice today in reducing the elapsed time of this cycle.

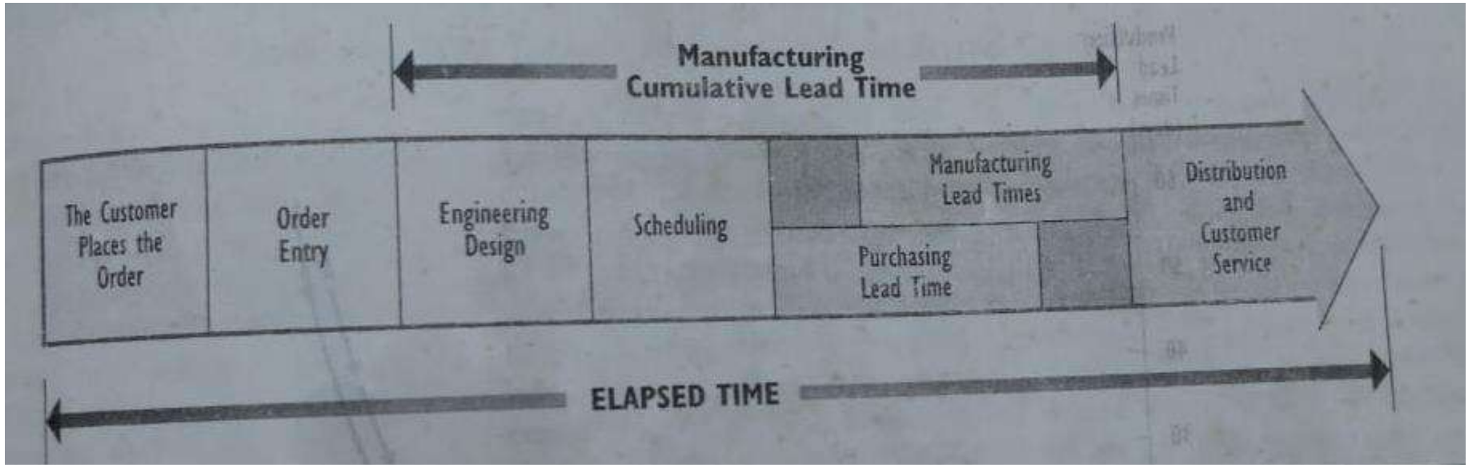


Figure: The time from Order-to-delivery cycle

In the traditional view of manufacturing, a key objective was to fully utilize production capacity so that more products were produced with fewer workers and machines. This kind of thinking led to large queues of in-process inventory waiting at work centers in manufacturing. Large queues meant that machines and workers never had to wait on partially finished products to come to them; therefore, capacity utilization was very high and production **costs were low**. Unfortunately, large queues of in-process inventory also meant that products spent most of their time in manufacturing **just waiting**. With this arrangement, companies would be ill equipped to compete in today's time based competition.

The following figure illustrates that this kind of traditional thinking can be deadly to companies that want to use speed as a weapon. In this figure, let us say that a firm is operating at point A, with a 96 percent capacity utilization and a 50 day manufacturing lead time. But if it is operating at point B, the capacity utilization is 60 percent and the manufacturing lead time is only 10 days. To shorten production lead times, 100 percent capacity utilization must not be the predominant objective. *In JIT manufacturing, drastically reducing the elapsed time of the order-to-delivery cycle has displaced the objective of 100 percent production capacity utilization in traditional manufacturing.*

There are many opportunities to speed up every step in the order-to-delivery cycle. An important way to reduce manufacturing lead times is to reduce queue lengths and waiting times of partially completed products at work centers in manufacturing by using queueing theory and queueing software. Another more often used way to reduce manufacturing lead times and work-in-process (WIP) inventory is by slightly increasing the production capacity.

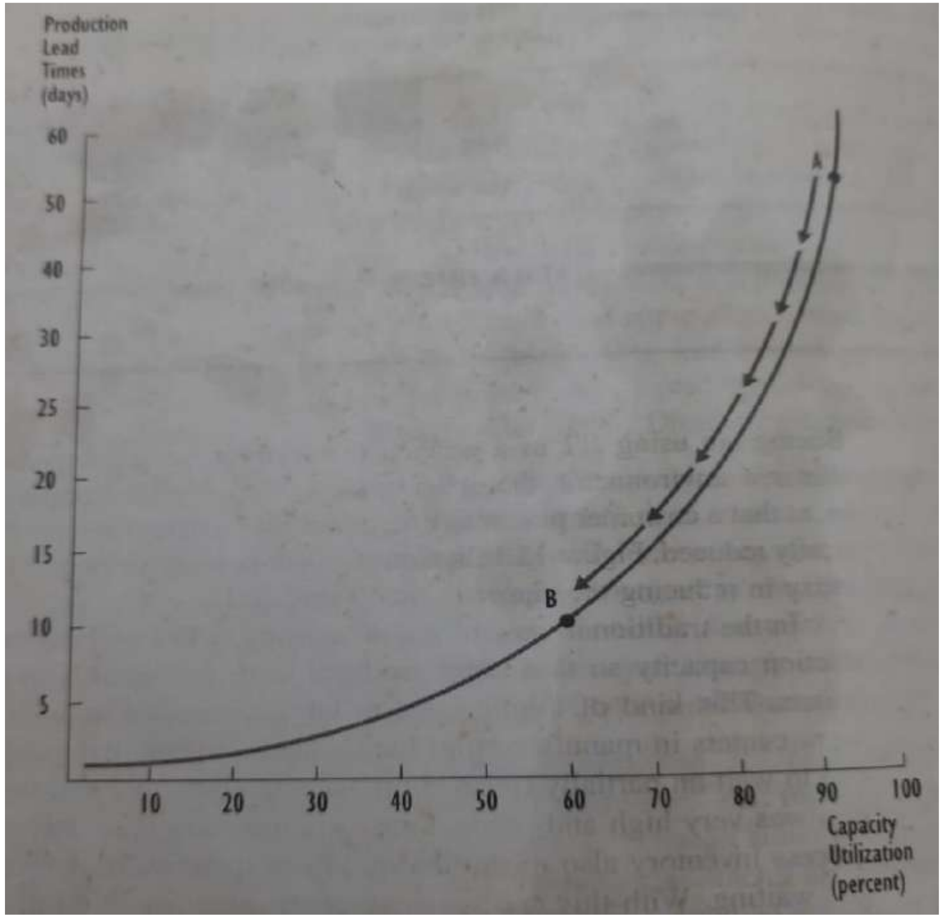


Figure: High capacity utilization: The enemy of time based competition

Prerequisites for JIT manufacturing

The main objective of JIT manufacturing is to reduce manufacturing lead times, and this is primarily achieved by drastic reductions in WIP. The result is a smooth, uninterrupted flow of products throughout production. Most successful JIT applications have been in **repetitive manufacturing**, *operations where batches of standard products are produced at high speeds and high volumes with materials moving in a continuous flow*. The Toyota automobile factories where JIT have started, are perhaps the best example of the use of JIT in repetitive manufacturing. In these factories, the continuous flow of products makes planning and control **rather simple**, and JIT works best in these shop-floor situations. Successful use of JIT is rare in large, highly complex job shops where production planning and control is extremely complicated. Smaller, less complex job shops have used JIT, but these companies have taken many steps to change operations so that they behave somewhat like repetitive manufacturing. Hence, JIT does not come free – certain changes to the factory and the way it is managed must occur before the benefits can be realized. Among these changes are:

1. Stabilize production schedules
2. Increase production capacities of manufacturing work centers.
3. Improve product quality.
4. Cross-train workers so that they are multi-skilled and competent in several jobs.
5. Reduce equipment breakdowns through preventive maintenance.
6. Develop long-term supplier relations that avoid interruptions to material flows.

At Toyota, for instance, there are both stable and level production schedules. The production schedule is exactly the same for each day of the month. This means that the same products are produced in the same quantities in the same sequence every day of the month. This approach to the MPS simplifies parts explosions, material flows, and worker job assignments. If JIT is to work, stable and level production schedules are necessary.

A fundamental requirement for JIT is to *increase the production capacity* of manufacturing work centers. Production capacities are usually increased in two ways, increasing production rates and reducing setup times at work centers. (Setup time is the time it takes to adjust the machine settings, replace materials, change tools, and do everything it takes to change over from producing one product to a different one at a work center).

By improving product quality, cross-training workers, reducing equipment breakdown through preventive maintenance, and establishing reliable workflows from suppliers, interruptions to production are minimized. Because workers are trained on several jobs, they can be moved about to other jobs as needed to work off any imbalance in work flows that may be caused by either quality problems or machine breakdowns.

With these factors present in manufacturing, the ultimate success of JIT is vastly increased.

Elements of JIT manufacturing/production:

The JIT can be discussed by examining its important components or elements: the underlying assumptions, its approach, its method of planning and controlling production, and several of its ongoing activities.

Eliminating Waste

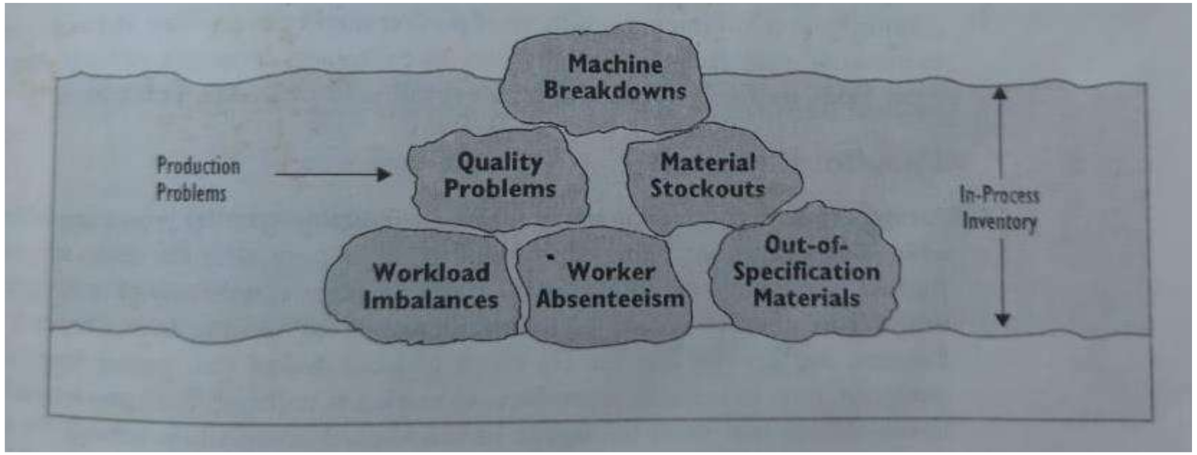
Eliminating waste of all kinds is the deep-seated ideology behind JIT. Shigeo Shingo, a JIT authority at Toyota, Identified seven wastes in production that should be eliminated, which are described as follows:

1. **Over production.** Make only what is needed now.
2. **Waiting.** Coordinate flows between operations, and balance load imbalances by flexible workers and equipment.
3. **Transportation.** Design facility layouts that reduce or eliminate materials handling and shipping.
4. **Unneeded production.** Eliminate all unneeded production steps.
5. **WIP Inventories.** Eliminate by reducing setup times, increasing production rates, and better coordination of production rates between work centers.
6. **Motion and effort.** Improving productivity and quality by eliminating unnecessary human motions, make necessary human motions more efficient, mechanize, then automate.
7. **Defective products.** Eliminate defects and inspection. Make better products.

Enforced problem solving and Continuous improvement.

In traditional manufacturing, in-process inventories allow production to continue even if production problems occur; thus high machine and worker utilization is achieved. If defective products are discovered, machines malfunction, or material stock outs occur, in-process inventory can be used to feed what would otherwise be idle workers and machines. The following figure illustrates how in-process inventory covers up production problems in traditional manufacturing. But, behind JIT is the continuous drive to improve production processes and methods. Towards that end, JIT strives to reduce inventories because high inventory levels are thought to cover up production problems. By drastically reducing in-process inventories, production problems are uncovered and production stops until the causes of the production problems are solved. Only when the machine is fixed, or the cause behind the stock out is found and corrected – only than can the production begin again. Thus, JIT is really a system of enforced problem solving. In other words, the continuous improvement system of JIT enforces the managers to continuously study the potential problem areas and solve them. Hence, continuous improvement is central to the philosophy of JIT and is a key reason for its success.

Figure: Uncovering production problems by reducing inventories.



People Make JIT Work

Businesses ultimately succeed or fail because of their people. JIT is no exception to this rule. Because JIT is a system of enforced problem solving, having a **dedicated workforce committed to working together** to solve production problems is essential. JIT manufacturing, therefore, has a strong element of **training and involvement** of workers in all phases of manufacturing.

First, and foremost, a culture of **mutual trust and teamwork** must be developed in an organization. Managers and workers must see each other as coworkers committed to the company's success. Work teams are encouraged to **meet together** to search for long-term solutions to the causes of production problems. Workers are also encouraged to **suggest better ways** of doing things from small suggestions to strategic issues. Along with an open and trusting culture, an attitude of **loyalty to the team and self-discipline** must also be developed. Workers are not free to go off on their own and try any method of doing their work according to any standard that they choose; rather, methods and standards agreed to by the team prevail.

Another important factor that is crucial to the success of JIT is the **empowerment of workers.** This means that workers are given the authority to take the **initiative in solving** production problems. Rather than waiting for guidance from above, workers have the authority to stop production at any time for such things as quality problems, machine malfunctions, or safety concerns. Groups of workers are then encouraged to work together to quickly get production going again. Having workers actively involved in problem solving is the objective of worker empowerment.

People, suppliers, workers, managers, and customers must all be motivated and committed to teamwork for JIT manufacturing to be effective.

Total Quality Management (TQM)

JIT manufacturing depends on a system of TQM being in place. Successful JIT manufacturing goes hand-in-hand with an organization-wide TQM culture. Just as everyone has to be involved in JIT, so also must everyone be involved in TQM. Total commitment to producing products of perfect quality every time and total commitment to producing products for fast delivery to customers have one essential thing in common: both are finely focused on the overall goal of satisfied customers.

Parallel Processing

An important part of JIT manufacturing is to exploit parallel processing wherever possible. Wherever possible, if the operations are performed in parallel (simultaneously) than performing in series (one after the other), manufacturing lead time can be reduced to a great degree. This concept is similar to simultaneous engineering, i.e. by doing product design and process design simultaneously, the time to bring new products to market is reduced. The same approach is taken in companies that want to engage inn time-based competition through JIT. Many operations can be made parallel simply through scheduling. If not possible, layout redesign and product redesign may be needed to achieve parallel processing. However, the additional costs in doing so can usually be more than offset by significant reductions in manufacturing lead times.

JIT Purchasing

JIT purchasing differs from the traditional perspective on purchasing. In JIT purchasing, companies tend to adopt long-term relationships with fewer suppliers. In exchange for long-term contracts, suppliers sometimes agree to special conditions such as locating the supplier plant within a certain radius of the JIT company, adopting total quality control techniques, and submitting to frequent inspections by company executives and quality specialists.

Benefits of JIT manufacturing

Some of the benefits claimed for JIT systems are:

1. Inventory levels are drastically reduced.
2. The time it takes for products to get through the factory is greatly reduced, thus enabling factories to engage in time-based competition, using speed as a weapon to capture market share.
3. Product quality is improved, and the cost of scrap is reduced. Product quality improves because of worker involvement in solving the causes of production problems.
4. With less in-process inventory, less space is taken up with inventory and materials handling equipment. Workers are close together so that they can see each other, communicate more easily, work out problems more efficiently, learn each others jobs, and switch jobs as needed. This promotes teamwork among workers and flexibility in work assignments.
5. Because of the focus in JIT manufacturing is on finding and correcting the causes of production problems, manufacturing operations are streamlined and problem free.

To obtain the benefits from JIT, however, companies have had to invest heavily in engineering studies and equipment modifications to achieve drastically reduced setup times, establish training programs that train workers for several jobs, and develop different business strategies to come up with stable and level production schedules. Unless the manufacturers are willing to commit to these new investments, they cannot expect to reap the benefits of JIT.