CHAPTER SEVEN

THE FOUR PRINCIPAL CONSTRAINTS IN INVENTORY MANAGEMENT
Inventories constitute a form of service. Every service has a cost. This cost rises faster than the rate of service. In other words, the extent to which inventories in general are assets depends on the extent to which they consist of "industrial muscle and not of industrial fat".

Inventories rapidly degenerate into industrial fat through lack of exercise. The muscle-tone of inventory is measured by its speed of movement. "Turn-over" is the term applied to this movement.

A manufacturer, especially in India, cannot have his inventory turn-over so quickly because -

1. It takes time to process/manufacture. Materials may spend from a couple of months to a year or two in process.
2. Things like spare parts are required critically and unpredictably.
3. Few manufacturing requirements can be brought 'off-the-shelf' and they must be brought in advance of actual needs.

In India, it has been repeatedly proven that the turn over ratio can easily be increased to 3 to 4 times a year, purely by internal measures which do not require a year to take effect, although the optimum inventory will vary from one type of industry to another.
The basic elements of Inventory Control

Before one can determine what one's optimum inventory should be, one must know something about the basic behaviour of inventory. The basic principles of inventory control are simple and consist of the order-size or economic order quantity (i.e. how much to get at one time), the order level (when to buy), the price at which the purchases have to be effected and its corollary, the quantitative aspect, while determining the prices, given the equal, if not more, importance.

Effecting purchasing can increase one's profits by:

1. Reducing the cost of the end-product by reducing the cost of inputs;
2. Increasing the productivity of the facilities for production;
3. Optimising inventories;
4. Increasing the value of the end-product to the customer while keeping the prices constant.

And doing all these things by getting -

(a) The right quantity (of)
(b) The right quality (at)
(c) The right time (for)
(d) The right price

These activities should be considered logically to see what the purchase function can do for an organisation as
In any Material Management set up, the purchase department plays a notable role to help actualise the objectives of the organisation.

Every organisation spends too much money, time and effort because all the concerned using departments (including the purchase department), look on these four principal constraints from a purely departmental point of view. At present, in majority of firms in India, a purchase department is judged almost solely by its success in supplying the indentor with what it needs. Economy in supplying is a subservient function. It is necessary here to underscore the point that it is the function of the organisation as a whole to resolve the problem of how to optimise the productive-mix by keeping centralised control while decentralising operations. The purchase department can then become an effective device for feeding back into the organisation the data required for matching requirements with availabilities so that decisions regarding quantity, quality, time and price could get translated into practical plane than remain mere watch-words.

The Right Quantity

Procurement of materials and services follows a chain of decisions and events often broader in scope than the clearly defined responsibility of any single functionary.
group in an undertaking. It is incumbent on the Materials Manager to keep the Management and the requisitioning departments constantly informed and advised of the right quantities to buy, especially -

(1) Supplier-wise, in order to negotiate blanket contracts and long term contracts with staggered deliveries;

(2) In terms of 'A' value, etc., in order to determine how many months' supply to buy, and whether the ordered quantity should be increased or decreased i.e. whether the periodic state of economy suggests that safety-stock be increased or decreased.

(3) In terms of those which need extra chase-up and preventive inspection and other forms of aid to the supplier.

(4) In terms of those which involve earlier financial outlay, such as part-payment in advance, or financial assistance to a small-scale manufacturer.

The right quantity for the using department may be, say, one each of an A, B and C value item. They may be needed together. But they should most probably be bought at different times. If the quantity bought at a time is too small, then higher retail prices will have to be paid; if
it is too big, the suppliers suspecting a distress purchase may inflate prices.

Many Companies in India claim that they cannot plan their purchases at all because special market-conditions they face do not permit a sufficiently accurate forecast of sales for a sufficiently long period. Actually, such claims generally prove to have little validity when they are objectively analysed. The instances quoted to substantiate this contention generally prove to be the exception. A sellers' market turns out to be the long-term loan. Most instances of the forecasted sales failing to materialize prove to be the result of inaccurate sales forecasts or of customers turning to the more expensive suppliers whose quality or delivery is more dependable, or of the Company not integrating its production capacity with that the Market wants. The more complex the task to be performed, the greater is the need for planning.

Right Quality

The right quality if determined in isolation by the indentor, will restrict the availability of the things to be chosen from, and will increase the price, and the safety stock. 'Quality' affects the quantity to be purchased and the purchase department should know most about the availability of substitutes so that the right 'quality' should be chosen only after it examines the commercial implications.
It needs time to do so.

Quality is the power to attain a standard, a standard being expressed in the form of one or more specifications, while the specifications state what is required, and the 'tolerance' of each equipment when 'one lays down the quality' of anything, one is defining the extent to which one wants any specification or specifications. When one measures quality, one is seeing to what extent the actual specifications conform to the desired specifications.

The word 'quality', however, cannot be divested of all the emotional connotations it has acquired. Quality, therefore, does not exist. Quality merely refers to an attitude of approval. It is, therefore, an act of judgement, an emotional state, not a physical fact.

To say that a thing is 'good' is merely to say that one approves of it, to say that a thing is excellent is merely to say that one approves of it very much. What then, is meant by its quality is excellent? Here is a case of semantic confusion par excellence. Here, by 'quality' one really means that the item having quality contains certain properties desired in greater measure than some other item with which it is being compared. If you say that the quality of a Mercedes is superior to that of an Indian made car, do you mean that it will give you more miles per gallon (it won't), or that for the Indian road
conditions, it is sturdy enough to withstand all the bumps and jolts and hence the discomfort (it is not), you are really saying that the Mercedes has a longer working life, and that its average performance during its working life will be superior to that of the Indian car. So you have laid down 2 specifications, viz. length of service and rate of service. You have then quantified both the specifications and found that the Mercedes has more.

First determine the end user or end-user, then determine what all properties you need, then quantify them, always calculating the cost of each specification and for the quality, i.e. tolerance of each specification. Only then can you know what value you will be getting for your money.

The Right Time

The Right Time for the user, differs from the right time for the Purchase Department for every material. For the user, the right time is the time when he needs a thing; for the organisation, the right time is based on factors such as, is the availability, the demand or the price seasonal? What is the trend of supplies and prices?

The most common supplier's failure is failure to deliver on time. There may be various reasons for such failure like manufacturing difficulties, shortage of raw materials, labour trouble, transportation difficulties and
bad management. The buyers skill is tested when a seller fails to deliver on time. He must immediately find out the cause of the failure and formulate a plan to cope up with it to avoid a shut down of production in his own undertaking, even though in some cases it may be necessary to start a second supplier on the item. Many delivery failures can be prevented by field expediting. The expeditor may stimulate the supplier's personnel to greater efforts. He can keep the buyer up-to-date with reliable first hand information on correct delivery status and can sometime assist the supplier in respect of changes in specification or quality in consultation with the buyer, and in many other ways.

Depending on the type of item, a Purchase Department should watch out for the and tabulate on paper, the results of the following factors:

(a) Heavy rains might affect a supplier's production by increasing the transport time for some of his materials.

(b) A Purchase Department should also find out whether the suppliers of its important users are getting their crucial supplies in time.

(c) It should also see whether there is any chance of a strike or a go slow in its suppliers' works.
In certain parts of India, such tactics are the rule either towards the end of a Firm's Financial Year, or when the agreement with the Trade Union is about to come up for renewal.

(d) It is also important to watch out for strikes on the transport-system; otherwise, one will not be ahead enough in the queue to live on alternate means of transport.

(e) Another significant time is either the period that marks the transition from one Five-Year Plan to another, or when some new Public Sector Project has finally received financial sanction to buy some of the same major supplies. There is a tremendous bulking of demands at these times, especially just before the expiry of the period sanctioned for expenditure. These large users are willing to pay any thing at such times, not merely to get the material but also in order to ensure that they will not be sanctioned less funds for the next period.

Accurate market-research requires periodic, regular and systematic field-work. This will enable one to know in time of any likely changes in the supply position especially in the seller's market, as we find ourselves in for the most of the stores.
The Right Price

This is a matter of supply and demand which are function of quantity, quality and time. The right price is not the cheapest price at any specific period of time. It is the amount which an organisation should spend over a period on the materials needed for making at the minimum cost the products to satisfy the types of customers it has chosen to cater to.

Most industrial buying, in a way, is forward buying because one anticipates, plans and buys before the actual need arises. In so doing, understandable, there is bound to be some element of speculation, of risk, in anything concerning the future. The main objectives of Forward Buying, besides an aid to reduce stock-outs, are:

1. To increase human productivity by reducing rush purchases and thereby get at a price which is economical and the right price rather one termed as a 'distress purchase'.

2. To stabilise and minimise long term costs through bulking and Blanket Contracts, etc.

Forward Buying does not necessarily entail the immediate payment for and receipt of supplies meant for future use. It is merely a promise to buy at certain future dates, at prices to be fixed at the time of the contract or at the prices prevailing on the stipulated date, and of quantities
either stipulated or not. For instance, in a Blanket Contract, one can specify a large number of items, all of which are available from the same supplier. This is suitable for items which are bulky, perishable and with fluctuating usage. Quantities need not be specified but prices may be fixed. Rate Contracts, much used by the Governments are very similar to Blanket Contracts. They obviate tenders. Approved personnel can buy from approved suppliers at approved rates.

In other words, it is the responsibility of the Purchase Department to judge who would be able to supply the required material at the best ultimate value for money and in the best combined factors of price, service and quality. They have to decide the most economic method of transportation and its rate consistent with the reliability of delivery.

Many large and highly integrated undertakings rely on outside suppliers for at least some components and materials. An undertaking will make certain components of its product and buy others. If the undertaking has no facilities to manufacture the component, or existing facilities can be better utilised for other purpose, demand for the component is temporary or seasonal, and for such other reasons, it would be advantageous to buy a finished component from an outsider. It is in this connection that sub-contracting assumes importance.
Industries which farm out their requirements will find that by carefully selecting such contractors and 'wet-nursing' or giving maximum assistance to them, financial, technical or managerial, they can earn handsome dividends such as price reduction of 10% to 25% and improved quality and delivery.

Application of standardisation and simplification of procedures can, to a considerable extent, result in economy in the use of materials and consequent cost reduction and thereby arrive at a correct appraisal of the price to both the buyer and the seller.
PART - III

7. **Four Principal constraints in Inventory Management**

The right quality, the right price, the right time and the right place. Importance of these constraints in the Indian Conditions and how these conditions are optimised in working situations.

8. **Evaluation Criteria in Inventory Management**

Return on investment concept in inventory management. Computation of the cost of carrying inventory. The relevance of the size and cycle of turnover. Use of ratios and other appraisal techniques.

9. **Sensitivity Analysis in Inventory Management**

The concept of the Product-life Cycle Impact of technological supercession in design, development and methods of production and material specifications on management decisions. The problem of uncertainties.

10. **Control Techniques in Inventory Management**

Use and mis-use of the concept of maxima and minima. The technique of ABC analysis. Application of Value-Analysis, Statistical Quality Control and PERT techniques in inventory control. Trends in application of more sophisticated tools of planning and Control.
CHAPTER EIGHT

EVALUATION CRITERIA IN INVENTORY MANAGEMENT
One of the important functions in Management is the control of performance. In order to achieve this, it is necessary to evaluate performance either of the individual functionary or the activities as a whole. The objective of evaluation, therefore, relates to the 'Control' function. These are the elements in the control process:

1. Standards that represent the desired performance. They may be tangible or intangible, vague or specific.
2. Comparison of actuals with standards.
3. Corrective action.

"Managers 'evaluate' in order to determine if their organisations are moving towards objectives in accordance with pre-determined plans and policies. Primarily the word 'evaluation' assumes assessment against some standard."


As materials account for 65 paisa per rupee of the sales value of an item it is essential for Management to know the standard of performance of their Materials Management Department and this can be considered on each of the objectives of purchasing viz. the right quality, the right quantity, the right price and the right time.

The overall performance of the Department and its success will be determined by the following considerations:

(a) Is the Department able to ensure a flow of materials at most economical rate for the continuity of production?
(b) Are the materials cost such as to make it easier for the end products to be competitive?

(c) Is the Department trying to achieve higher productivity in terms of materials cost and materials economy.

Inventory control is a planned method of determining what to indent, when to indent, how much to indent and how much to stock so that purchasing and storing costs are the lowest possible without affecting production or sales.

Without proper control, inventories have a tendency to grow beyond economic limits. Funds are tied up unnecessarily in surplus stores and stocks, productive operations are starved and the finances of the plant are severely strained. Lack of control over inventory also leads to an excessive consumption or operatives are liable to become careless with unrationed supply of materials.

Return of Investment

Industrial economics is vitally different from Trading Economics in that the pressure for maintaining liquidity is much greater than in trade. In trading, almost the entire capital is invested in stock-in-trade which possesses inherent convertibility. In industry, however, liquidity has to be maintained with only 10-20% of the total capital in the form of finished goods.

The following table gives an analysis of capital invest-
ment in 29 major industries in India as given in the Central Statistical Organisation Report:

<table>
<thead>
<tr>
<th>Category</th>
<th>Value (Rs. in lakhs)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total capital</td>
<td>1,214.72</td>
<td>100.00</td>
</tr>
<tr>
<td>Fixed capital</td>
<td>631.06</td>
<td>51.95</td>
</tr>
<tr>
<td>Working capital (inclusive of inventories)</td>
<td>583.66</td>
<td>48.05</td>
</tr>
<tr>
<td><strong>Inventories</strong></td>
<td></td>
<td><strong>100.00</strong></td>
</tr>
<tr>
<td>(a) Raw materials</td>
<td>279.99</td>
<td>23.05</td>
</tr>
<tr>
<td>(b) Finished goods</td>
<td>197.72</td>
<td>16.28</td>
</tr>
<tr>
<td>(c) Work in progress</td>
<td>90.18</td>
<td>3.46</td>
</tr>
</tbody>
</table>

It will be seen from these figures that 99.44% (i.e. Rs. 43.46 lakhs out of Rs. 58.05 lakhs) of the working capital is in the form of inventories.

The need for scientific inventory control in industry can also be established from the consideration of return on capital which is one of the principal objectives of any undertaking:

\[
\text{Return on capital} = \text{Profit} \]

or

\[
\text{(Rate of return)} = \frac{\text{Profit}}{\text{Capital investment}}
\]
and it can be maximised by increasing profit or reducing capital investment or both. There are limitations to increasing profits as it depends upon so many external factors like competition, government control, etc., and is often beyond management's control. Capital is both fixed and working. Fixed capital is in the form of buildings, land, plant and machinery, and is fixed any way and very little can be done to reduce it, once the expenditure has been incurred. There remains the working capital and it will be seen from the table in the preceding paragraph that inventories tie up a large part of the working capital.

Fortunately, inventory investment is most responsive to various controls and appraisal techniques. For example, A.B.C. analysis affords a sound basis for selective Inventory Control. Such inventory control carried out on a scientific basis can reduce inventory investment very considerably. With a reduction in inventory investment, the total capital investment is reduced, thus increasing the return on capital. The inventory carrying cost which is a revenue expenditure also declines and correspondingly profit increases, thus raising the return on capital.

Computation of the cost of carrying inventory

All forms of inventory-control were evolved to answer two basic questions:
(1) of what items should a fixed quantity be bought, but at varying intervals, and
(2) what items should be bought at fixed intervals, but in varying quantities.

What quantity or how many rupees worth to buy at a time is the real implication of fixed quantity and this is called Economic Order Quantity (EOQ). The EOQ depends on the factors -

1. The cost of placing an order.
2. The cost of carrying inventory.

As one of these factors increases, the other decreases and vice versa.

**Inventory-carrying costs**

(a) The cost of money - this can be looked at in three ways:

1. The interest one pays. This varies from 8% to 18% and may exceed the savings expected from the concessions offered for a bulk purchase. For example, a Public Sector Firm bought Rs. 50 million worth of certain stores in order to benefit from a 10% concession on quantity purchase. 80% of this stores lay idle for the most 4 years, the total inventory carrying cost coming to Rs. 30 millions.

2. The interest one could have earned by loaning out money on the open market at a higher rate.
(3) The 'opportunity-cost' of capital - This is the best criterion even if unlimited funds are available, for it shows what one could earn from a sum of money if one invested it in the most profitable manner open to one.

(b) Storage: This cost consists of the expenditure on the physical facilities needed in connection with storage, as well as the administrative costs. The physical facilities include the storage-buildings, the racks, handling equipment. The administrative costs include the expenditure on the store-keeper and his staff, as well as on those in charge of stores-audit. Any cost which, functionally, can be considered as a storage-cost should be included under this heading such as costs of handling and internal movement in the factory for making stores mobile, etc.

(c) Deterioration: This is a much bigger cost in India than in, say, the U.K. or the U.S.A. Humidity, heat, floods, insects play havoc with stores to an unknown extent. Preservation of stores is an art as well as a science and it is indeed tragic that many industries in India do not pay much attention towards this nor have any one made an integrated study of this 'cost'.

(d) Obsolescence: Obsolescence is not merely technological in the sense that it confines itself to design or engineering changes only. Obsolete stores are also
non-moving stores, raw materials for a product which has been discontinued, stores unsuitable for a particular purpose, etc. When many items are stored it is inevitable that some of them may not be used, will shrink or disappear or will spoil. Needs cannot be estimated with perfect accuracy even with the most rigid inventory control systems. The general rule is never to hold inventories for which there is no immediate need. In fact, companies sometimes dispose of materials even when there is a definite future need for them. If stocks are held long enough, the accumulated carrying charges will exceed their value.

(e) Theft: This can be to a sizeable amount, at times.

(f) Insurance: This comes to about 0.5% of inventory investment.

The total cost

The sum total of these costs, listed above, result in the total cost and the average inventory carrying-cost of most Indian firms is at least 20% inspite of such usage of sophisticated techniques of Inventory Management. This cost is abnormally high, indeed a paradox.

Some experts or consultants on Inventory Control badly mislead Managements by stating that the inventory carrying cost should be calculated on the average inventory i.e. on half the quantity purchased during any given period.
In essence they say - "If you buy, say Rs. 100 worth at the beginning of any period, X, and consume it, then it will be finished at the end of the period X. So your average inventory during that period will be $\frac{100 + 0}{2}$ i.e. 50.

Such people mislead because they fail to mention the importance of the time which elapses after an organisation has paid for materials and before those materials earn revenue.

I believe that inventory carrying charges should be calculated on the actual amount which has not earned any revenue. This is the best way of ensuring that an organisation uses capital efficiently. The actual amount which has not earned any revenue consists of a rate of 23% per annum is not unreasonable in India, even if one takes not the opportunity cost of capital but the interest rate.

The cost of purchasing

The cost of placing an order is the second constituent of the EOQ. One could break up the cost of placing purchase orders into various categories. Effective materials management and operations research, various techniques of purchasing like Blanket Contracts and Running Contracts can reduce the number of orders to be placed.

The table below shows how the inventory-carrying-cost increases with an increase in the quantity acquired at one time, while the purchase-cost drops. You will note that
there is an optimum quantity which minimises the sum of 2 costs, irrespective of whether one takes the inventory costs as 25% of the total inventory (i.e., the quantity delivered) or of the 'average' inventory.

**B Q Q Table**

<table>
<thead>
<tr>
<th>No. of orders Qty.</th>
<th>Inventory-carrying Cost</th>
<th>Purchase Cost</th>
<th>Total Annual Cost (3+5)</th>
<th>Total Annual Cost (4+5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>On Full (2)</td>
<td>On Average (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td></td>
<td>(3)</td>
<td>(6)</td>
</tr>
<tr>
<td>1 2000</td>
<td>300</td>
<td>250</td>
<td>20</td>
<td>520</td>
</tr>
<tr>
<td>2 1000</td>
<td>250</td>
<td>125</td>
<td>40</td>
<td>290</td>
</tr>
<tr>
<td>3 667</td>
<td>167</td>
<td>83</td>
<td>60</td>
<td>227</td>
</tr>
<tr>
<td>4 500</td>
<td>125</td>
<td>63</td>
<td>80</td>
<td>205</td>
</tr>
<tr>
<td>6 333</td>
<td>84</td>
<td>42</td>
<td>120</td>
<td>204</td>
</tr>
<tr>
<td>12 167</td>
<td>42</td>
<td>21</td>
<td>240</td>
<td>(min)</td>
</tr>
</tbody>
</table>

**Annual Consumption**

Rs. 2,000

Value of inventory if it has been paid for but has not earned revenue

Rs. 2,000

Value of Average Inventory

Rs. 1,000

Inventory-carrying-cost

25% per annum.

Purchase - cost

Rs. 20 per order.

The same thing can be represented graphically (see next page).
EOQ TABLE BEING REPRESENTED GRAPHICALLY
Note that the curve 'total cost' which is the sum of the ordering cost and the carrying-cost, flattens at the bottom, and towards the right. This means that your EOQ will not change significantly, even if you are a bit off in your calculation regarding your carrying-cost or order-cost, and that it is better to err by increasing your EOQ than by reducing it.

**Economic Order Quantity**

The economic order quantity can be calculated by means of this simple and most commonly used formula:

\[
EOQ = \sqrt{\frac{2AS}{I}} \text{ rupees}
\]

where \( A \) = Annual consumption of the items in rupees.

\( S \) = Ordering cost per order (for purchased items)

or set-up cost (for manufactured items)

\( I \) = Inventory carrying cost as a percentage of the total inventory value.

For every item purchased and held in storage, there are two major expenses — the ordering cost or set-up cost \((S)\) and the inventory carrying cost \((I)\). The ordering cost, as briefly referred to earlier, includes the semi-variable and variable cost of purchasing, receiving, inspection and passing bills. Inventory carrying cost includes cost of storage and handling, estimated loss due to deterioration, obsolescence...
and wastage, cost of preventive measures adopted against deterioration, insurance charges on money locked up. Minimum cost inventory occurs at the point where the ordering cost and the inventory carrying cost are equal. The Planning Commission has estimated that in India, ordering cost ($S$) generally amounts to Rs. 10 to 20 per order or replenishment and inventory carrying cost ($I$) varies from 15% to 20% of the total inventory value per annum. Since the ordering cost and carrying cost vary only with the number of orders and with the value of purchases and not with the nature of the item to be purchased, it is not necessary to calculate the EOQ for each and every individual item. For everyday use, it is possible to incorporate EOQ data for different levels of annual consumption into tables which need not be changed so long as the values of $S$ and $I$ remain the same.

Assuming $S = Rs. 10$ and $I = 20\%$, an illustrative table incorporating economic order quantity and cost data for seven values of annual usage is given below:

<table>
<thead>
<tr>
<th>Annual Usage (Rs.)</th>
<th>Economic order quantity (Rs.)</th>
<th>Time supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>40,000</td>
<td>2,000</td>
<td>18 days</td>
</tr>
<tr>
<td>10,000</td>
<td>1,000</td>
<td>3 weeks</td>
</tr>
<tr>
<td>5,000</td>
<td>500</td>
<td>6 weeks</td>
</tr>
<tr>
<td>4,900</td>
<td>700</td>
<td>7.5 weeks</td>
</tr>
<tr>
<td>1,600</td>
<td>400</td>
<td>3 months</td>
</tr>
<tr>
<td>900</td>
<td>300</td>
<td>4 months</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>1 year</td>
</tr>
</tbody>
</table>
Size and cycle of turn-over

In business all efforts are directed towards achievement of the general objectives of business and the two most general economic objectives are survival and profits. Therefore, it is no exaggeration to say that inventory control can make or break a company and hence the importance of inventory management.

When companies have too little inventory and run out of stock, manufacturing efficiency is bound to be hurt, cause interruption of production and raises costs. The situation is equally bad for the company that carried too much inventory in-as-much as its costs will be so high that it would not make any profit on the business it gets by having material available. Inventories tie up a company's capital and they generate storage costs. It does not take too much imagination to grasp how clever inventory management can make a tremendous contribution to company profit objectives.

When inventories are low in relation to sales, less capital is tied up in inventories. This, in turn, increases the efficiency with which the company's capital is utilised, so that return on investment is higher. Also, storage and carrying costs of inventories are lower when turn over is high. In other words, inventory turn over = sales divided by average inventories. Hence a high inventory turn-over become one of the primary objectives in almost every
To achieve the objective of high inventory turnover, the Materials Manager should institute programmes to reduce the number of items carried in stock. He should persuade vendors to carry special stocks available for immediate delivery, work to tighten lead times and use various other techniques that would enable to have planned inventories. But in many phases of materials management, there is a conflict of objectives in inventory management. The objective of high inventory turnover conflicts with the objective of continuity of supply and other objectives. Of all business assets, inventories are the least stable and most difficult to control. Bad inventory planning has been one of the major causes of almost every business recession.

The major reason of difficulty in managing the inventories is the inability to forecast accurately. When a Materials Manager adds to inventory, he is anticipating a need for the material. In many cases, the need comes later than anticipated and sometimes it never materializes at all. The result is excessive inventory. Or, if demand comes sooner or is stronger than anticipated, the inventory is inadequate.

The materials cycle is remarkably sluggish. Typically, more than a year may pass before a quantity of raw materials is transformed into a finished product. Theoretically, it would take less than a week to perform every operation
necessary to transform raw materials into a product; but materials spent months either in various stock-piles or in transit between operation or plants. Hence, no business can operate without inventories, especially when the materials cycle is long and complex. It needs then as a protection against uncertainty, for efficient processing of materials, and to permit transit and handling. Inventories protect against unforeseen failures in supply or increases in demand and it protects production against unanticipated delays. Production at various stages of a manufacturing cycle can never be synchronised perfectly; inventories take up the slack when one stage operates at a rate different from that of the preceding or succeeding stage.

The use of ratios

No Materials Manager is expected to be an expert financial analyst. But he should be sufficiently familiar with Balance Sheets and income statements to make intelligent comparisons of competing suppliers and spot individual strengths and weaknesses.

One of the best approaches is to calculate various financial ratios for the supplier and compare them with ratios for competing suppliers.

1. The current ratio

This is the ratio of current assets to current liabilities.
It indicates the ability of the Company to pay its immediate obligation. Most analysts agree that it should be at least 2.5 and that when it gets below 1.0 the Company usually is on the brink of default on its obligation. Inventories cannot be quickly converted into cash, so they are excluded from current assets. If a manufacturing Company is in good financial condition, this "quick ratio" should be at least 1.5 which is a measure of better liquidity.

2. Profit ratios

Profitability can be measured by earning both as a percent of sales and as a percent of net worth. Average earnings on sales and net worth vary from industry to industry and also from year to year. Large companies tend to be more profitable than small firms.

3. Debt Ratios

A Company that is heavily in debt will have difficulty raising money to invest in improvements. There are two ratios that measure the extent of a Company’s indebtedness. The ratio of funded debt to net working capital should rarely exceed 1.0. The ratio of current debt to tangible net worth should normally be under 0.75.

4. Inventory Turnover Ratio

Dividing net sales by inventories indicates how rapidly
the Company is turning over its inventories. This is a barometer of the Company's material management skill.

The ratios given above are danger signals. A Material Manager can successfully deal with a supplier who is financially marginal for years, but he should not do so blindly. Whenever any of the key financial ratios of a supplier are sub-standard, the Materials Manager should investigate.

Other appraisal ratios

(1) Ratio of total inventory to sales - (Average inventory of raw materials and stores, work-in-progress and finished goods would constitute the total inventory).

(2) Ratio of - (a) Finished goods to sale.
   (b) Work-in-progress to finished goods.
   (c) Work in progress to raw materials and stores.

(3) Ratio of average inventory of raw materials and stores to consumption of same.

Various other appraisal techniques

Although there is no fool-proof statistical method for evaluation of performance, certain statistics can give a fairly good indication, such as -

(1) Analysis of moving and non-moving items.

(2) Progress on standardisation and variety reduction and implication thereof in financial terms.
(3) Inventory carrying cost.

(4) On how many occasions did stock-out occur.

(5) On how many occasions were "Rush" purchases made.

(6) Reduction in stock values as a direct result of better vendor performance (like quicker deliveries or stocking arrangements by vendor); better fixing of minimum and maximum stock levels, etc.

(7) The average cost per purchase order issued during the year.

(8) The average cost of the Purchase Department per rupees of purchase during the year.

(9) The ratio of purchase staff to the total employees of the organisation.

(10) The annual materials cost as a ratio of the total production costs.

Other considerations for appraisal include the following:

(1) The extent to which purchase research and vendor analysis is conducted.

(2) The transportation and materials handling costs and time for the movement of important raw materials.

(3) Efficient disposal of scrap and surplus.

(4) Systematic value analysis programme.

The above list is by no means exhaustive and it is up to the Materials Manager to set standards for himself and judge his own performance apart from any appraisal made by management or any outside agency.
CHAPTER NINE

SENSITIVITY ANALYSIS IN INVENTORY MANAGEMENT
What techniques are available for Inventory Management? How have they been used in practice? What has been accomplished with them?

Most manufacturing companies employ a substantial amount of capital in the form of Inventories. Also large is the expense incurred for carrying on fluctuation associated with Inventories. It is indeed unfortunate that the rule of thumb and intuition very commonly determine how much capital a company invests in inventory and how much inventory functions are performed.

Mathematical techniques designed to serve as guides in making certain types of Inventory Management decisions have long been available. Thus, the history of economic order quantity (E.O.Q.) formulas for how much to purchase (or economic lot size formulas for how much to manufacture) has been traced back for more than fifty years. In recent years, the subject of inventory management has engaged the attention of numerous mathematical analysts and an extensive literature has evolved which encompasses statistically based re-order point (ROP) formulas for when to order. Moreover, data processing equipment is now available to aid in solving problems which were formerly uneconomical to attempt.

Nevertheless, relatively few of the companies approached did report the application of these mathematical concepts to their own inventory management. This can be partly attributed to the lack of widespread familiarity with the concepts. Partly too, it is a reflection of the practical problem of converting these mathematically based concepts into the working systems which can be operated routinely by people who are not particularly versed in mathematics.

Since the companies chosen for interviews were largely those that had demonstrated an interest in Modern Methods of Inventory Management, it must be concluded that the actual use of these techniques is less frequent than the literature on this subject might lead one to believe. They are confident, however, that the techniques have improved management decisions by permitting Management to set inventory policy consistently for the thousands of individual items without being swamped by the tremendous details involved in reviewing each item separately.

**SENSITIVITY ANALYSIS**

The estimates of the costs of carrying and ordering inventory are very rough and often difficult or impossible to support by reliable accounting data. To what extent can the results of the Mathematical analysis be relied upon when the basic cost figures are lacking in precision.
When the economic order quantities are computed from imprecise cost estimates, factors emerge which tend to make the estimates or projections to deviate from the pre-determined or original positions, resulting in a lower return of investment than anticipated.

Sensitivity analysis is a scientific exercise, which leads to identification of factors that disturb any area of pre-calculated and estimated standards. Should there be a marked variation in the product mix, or attempts of large-scale diversification or acute crisis on account of non-availability of raw materials, the one area that gets appreciably dislocated is the Inventory holding as the consumption pattern is disturbed and gets lopsided. The object of sensitivity analysis is therefore to correct the adverse trends and introduce corrective measures by:

1. identification of factors which tend to cause the deviations;
2. the extent or the varying degrees to which these factors cause upsets;
3. areas where such disturbing factors can be corrected and effectively dealt with and also show such factors that cannot be brought under the orbit of correction, and
4. finally, the assessment of the total impact, i.e., the sum-total of the variations in the
overall management strategy and planning—its repercussions on the net results i.e., reflection on profit consequent to inventory costs shooting up.

Perhaps the best approach to measuring effectiveness of inventory practices would be one that attempted to measure directly those costs that the inventory control system is designed to minimize. As explained and detailed in preceding pages, these costs usually include carrying costs, ordering costs, and stockout costs.

"It is true that some of these costs are very difficult to determine from existing records and that perhaps the best that can be done with them is to make an informed guess. What the inventory controller really needs is an accounting that facilitates the computation and the estimation of the variables of inventory management. Conjecture and informed guess may still be necessary, but the inventory controller needs a type of accounting that presents the magnitudes in a form relevant to inventory decision making. He needs a type of accounting that emphasizes cash flows, one that facilitates the implementation of marginal concepts, and one that is framed in terms of probabilities."  

1 Techniques in Inventory Management. Report - 40 National Association of Accountants.
Errors that management may make in forecasting significant estimates such as sales volume, sales price, product purchase or production prices, operating costs, capital investment and project life may cause the estimated rate of return for a given investment to be higher or lower than the rate of return that is actually realized.

"Analysis cannot eliminate errors in estimating which affect rates of return nor can analysis eliminate, those risks involved in the selection of projects which would require more resources (e.g., capital, materials, time, effort) than the potential returns justify. However, examination of the sensitivity of measures of return to errors in the underlying estimates can help to indicate in what areas the greatest risk lie. On the basis of such determinations, management can then decide whether to investigate certain estimates more thoroughly before making a final decision or to reject a proposal outright as being too risky to warrant further investigation. If management does decide to investigate certain areas more intensively as a result of examinations of sensitivity, it may be able to improve its estimates and thereby reduce the risks of making a wrong choice."

1 Sensitivity analysis in making capital investment decisions, William C. House - Literature of National Association of Accountants.
**Sensitivity cannot be measured precisely**

The sensitivity of estimated rates of return to errors in estimates cannot be measured precisely. There are several reasons for this. First, based on its past experience, management determines the relationships between variable which, in turn, affect the rates of return; these relationships, however, may not hold completely true in future. Second, in its examination of the sensitivity of rates of return to errors in estimating individual variables, management may have to ignore the fact that a change in one estimate (e.g. sales volume) may cause changes in another estimate (e.g. inventory holding and the operating expenses), because such cause and effect relationships are difficult to measure. The lack of actual data on how much one estimate will vary if another is altered may make it difficult for management to determine precisely the effects of errors in estimation. The determination by management of which estimates should be investigated more thoroughly can be made on the basis of whether or not the sensitivity of estimated rates of return to errors in any given estimates is significant. Management should examine such estimates more thoroughly or else it should collect more information in an effort to reduce errors in forecasting and the likelihood of making the wrong choice. An incorrect decision is one that Management
could have avoided if more complete information about the future had been available. It may be possible for management to reduce its uncertainty about expected values of estimates by improving its forecasting.

**PRODUCT LIFE CYCLE**

**Product and Process**

The two pivotal concepts in any manufacturing plant are product and process: the first refers to the end result of the plant's operations in terms of useful goods. The second refers to the means of production with which the plant is equipped. The coming together of product requirements and process restrictions determines the nature of product which is the fundamental parameter identifying an industrial plant. The functional properties of the products are first considered separately from the technological character of the process. This permits each to be analysed in its turn, so as to discover eventually their mutual connections; that is, what demands do the properties make of the conceived process; what restrictions does the process impose on the products.

**Concept of Product**

Of first importance is the definition of the product being examined. Is it really just one item or is it a group or family of items? To answer this question, we need
to know how the customer requests and the Company stocks different types, capacities, formulations, properties, sizes and so on, then these are many products and not just one. It does little good to tell a customer that there is a large inventory in a product when the customer wants a particular type and all the inventory is in some other sizes and capacities. In planning any inventory, therefore, there are certain fundamental principles which are to be borne in mind, primarily the product itself and its acceptability norms, i.e. its life-cycle which is likely to be affected by future probabilities, the exact impact of which cannot be immediately evaluated, nevertheless have a direct bearing on inventory policy.

**Product life**

How much of customers' insistence upon getting variations from standard is due to their personal whims and fancies? How much results from failures of existing designs to meet their needs. Could it be that customers trying to get better features in their products that they have seen in competitors' designs? Are some of these designs out of date?

Like people, products have life spans. Some are short. Many are killed by changes in technology. It is therefore necessary that one has to watch the product life. A schematic diagram is given on page 145. A Product sales tend
Design Life:

Product sales tend to decline from a peak as competitors develop similar and better designs.
to decline from a peak as competitors develop similar and better designs.

The solid curve suggests one main premise. Inventories of raw and finished materials may become inflated. Avoid becoming overstocked. One way is to maintain a close follow-up on differences between forecast and actual sales. A better plan is to anticipate change in quantities. You can do this by plotting curves like the solid line above. These charts should carry also a guiding yardstick of general business conditions. Without such an index, one cannot tell whether sales are rising because of product popularity or more spending.

**Product life tends to change**

Changes in sales of a given product are caused by (a) business conditions, as stated above. (b) modernising designs - like influences such as style change, saturation and competition. (c) durable products tend to level off. The degree is affected many times by the advances of competitors.

What happens is suggested by the dashed lines on the above chart. You may follow behind and add some improvements just to keep pace. These should help postpone the decline as depicted by line A. You may be spurred to do better than competition. The result could be an upsurge in sales as portrayed by curve B. The best plan, of course
is to be there first with better designs. Then trendline C. would consist of several continually rising extensions.

**Customer needs**

Much depends upon how well the products meet customer needs. Customer desires are changing with technological developments. Some are altered by adoptions of new materials. Others are caused by different demands from their customers.

Variations of customer needs point up several practical problems of production control. One must watch the inventories. Engineering changes may make obsolete certain raw materials.

**PROBLEMS OF UNCERTAINTY**

In these days of strong but often unpredictable sales, safety stocks afford, a method of buying short-term protection against the uncertainties of customer demand. They are the additional inventory on hand which can be drawn upon in case of emergency during the placement of order by the customer and receipt of material to fill the order. In practice, however, their potentials are often needlessly lost.

One reason for the failure is a very practical one. Because safety stocks are designed to cope with the
uncertainties of sales, they must be controlled by flexible rules so that conditions can be met as they develop. But sometimes the need for flexibility is used as an excuse for indefiniteness. The methods used by existing systems in industry often violate sound control concepts. The economy of the company is maintained in the face of instability and inefficiency in the inventory-control system, only because of the constant attention, exercise of over-riding common sense, and the use of expediting and other emergency measures outside the routine of the system.

It is possible, however, to have inventory controls which are not only flexible but also carefully designed and explicit. But the task needs special analytical tools; in a complicated business it defines commonsense judgement and simple arithmetic. Methods must be employed to take direct account of uncertainty and to measure the response characteristics of the system and relate them to costs. Such methods are the distinctive mark of a really modern, progressive inventory control system.

The following are some of the points relevant to the topic here.

Uncertainties arising from sales

Basically, there are two different types of inventory replenishment systems designed to handle uncertainty about
about sales - fixed order, commonly used in factories as in bins of parts or other materials; and periodic re-ordering, frequently used in warehouses for inventories involving a large number of items. While the two are basically similar in concept, they have somewhat different effects on safety stocks and choice of one or the other, or some related variety, requires careful consideration.

The fundamental problem of setting safety stocks under either system is balancing a series of types of costs which are not found in the ordinary accounting records of the company—costs of customer service failure, of varying production rates, of spare capacity, and others. Often specialists in inventory management can find the optimum balance with relatively simple techniques once the cost data are made clear.

**Uncertainties arising from product**
- Specification change inherent in material itself. The possibility of the product becoming obsolete is often critical and the greater the chance of obsolescence the greater the risk in carrying large inventories. The assessment of the probability of a product becoming obsolete by a certain time can be developed from past experience with related products or by judgment. The factors to be considered when deciding the time in which a product is liable to become obsolete are:
(1) advances in technology resulting in composites producing a better product/design.

(2) Changes in material specification or development, of one's own product thus relegating quantities of components to the realm of dead stock.

(3) Managerial decision to discontinue production of the item.

Uncertainties regarding replenishment

No matter how well planned inventory control is there are a number of uncertain factors which could upset all planning and hence allowances are to be made for these. Some of the factors are:

(1) Both domestic and International Political atmosphere.

(2) Seasonal price fluctuations e.g. items such as food products.

(3) Government import licence policy and availability of shipping for imported items.

(4) Internal transportation difficulties.

(5) Dislocation on account of weather conditions, etc.

THE TECHNOLOGICAL PREPONDERANCE--THE MANAGEMENT TECHNOLOGY GAP--SUPERCESSION IN DESIGN, DEVELOPMENT AND METHODS

The ability to bring inventions and innovations into use more quickly poses two problems. The first is the
effect which the new product or service will have on the consumer. The second is the effect which the need to cope with the new technology has on the system and those within it who are concerned in its introduction and production. Technological life has been characterised more by revolution than by evolution and consequent technological upheavals could be better described in the words of Sir Paul Heiley, Director, Council of Industrial Design, U.K.: "The history of design in manufacture over the last two hundred and fifty years could almost be compressed into three words - integration, disintegration, reintegration for that broadly has been the sequence of development from the days of handicraftsmanship, through the mechanization of the first industrial revolution, to the present age of swiftly changing technology." Thus, in broad terms, the effects of the more rapid rate of change of technology on the consumer may be summarized as saying that we—both as individuals and as societies—are continuously being offered opportunities for possessing or doing things in a way which was not previously possible and that, in consequence, we find ourselves subjected to experiences and strains which, being novel, we regard with caution. If, in sensing an element of risk to us as individuals, we develop a positive resistance to any change, how much more resistant may be the cumbersome society of which we form part.
The Management/Technology Gap

But when we come to the problems of those who are directly concerned in the production of goods we add a number of factors to those which we experience as consumers.

As managers of a production system, we are concerned with the smooth running of our department, and particularly with the profitability of our operations. In everything we do, we are dealing with people who bring to their activities in the production system such the same attitude of mind as they do in their activities as consumers and such the same resistance to change. We find ourselves constrained by the traditions and habits of the group for whom we are responsible. The innovations which we can introduce in the normal day-to-day operation of the system must be weighed seriously and should preferably represent only a small change from the current norm.

But in our role as managers of innovation—as technologists—we are charged by the nature of our work to cause change. Indeed, as the rate of change of technology increases so we are expected to introduce a continuing series of changes, frequently introducing a new product before the previous one has run its course. Furthermore, as our work moves further away from the maintenance of current technology towards research, so the changes which we are to introduce are expected to be ever more radical in nature. Thus, if successful, the solutions to the
problems which the technologists have been set may well prove
to be incompatible with the business within which they are
operating. Thus, either the business must change, or a
new business must be created, or these solutions are replaced
by others--more trivial--which are compatible with the
business and capable of immediate implementation.

There is, of course, no simple formula which can be
looked up in a book and applied to any situation. Rather,
there are some general principles supported by a plethora
of techniques and methodologies which must be applied with
a shrewd sense of judgement. The principles of importance
in the context of this paper can be summarized as follows:

1. **Technological Opportunities**

   It will be increasingly necessary for top management
to add to their conventional appreciation of business oppor-
tunities an appreciation of the opportunities for techno-
logical change.

2. **Market Needs**

   There will need to be a greater understanding of the
significance of technological change in assessing market
needs. It is not sufficient to assume that the consumer
already understands the consequences to him of products
about to be introduced to the market.
3. **Objectives**

It will be increasingly necessary for objectives to be expressed in such a way that the range of their nature is fully appreciated, and that the consequences of successful solution of the problems to be overcome in achieving such objectives are adequately understood.

4. **Business systems**

It will be necessary to ensure that steps are taken to modify the business system, to enhance the human relationships within it, and to develop the necessary skills, at the same time as the development of the new technology.

5. **Obsolescent systems**

On both a business and national basis, we must face the fact that fossilized and archaic systems of ordering our affairs may force us to continue to use obsolete technologies, thus leaving the new technology to a competitor elsewhere who is uninhibited in his scope for exploitation.

**IMPLICATIONS OF TECHNOLOGY FOR BUSINESS**

In practice, the management of a company has to make positive decisions on the technology in which they will invest; on specific product in that technology; and on a specific manufacturing process for that product. Uncertainty and complexity are inherent in these decisions, and manage-
ment will accordingly hedge its bets as much as possible. Nevertheless, these decisions will be taken against a background of the traditions of the company, the environment within which it operates, and some assessment of the future.

Any study of the implications of technological change for business shows both that there are usually historically recognizable trends and that at any time in time there are frequently potential deviations from and variations of these trends which provide options through which a business may benefit from technological developments. Assessment studies of the future are therefore most beneficial when they show the option open to a business and the consequences of following them.

Market needs and technological forecasting are of growing importance in helping businessmen and technologists to get the picture of the future into perspective as a means of understanding more clearly where their company stands in the cycle of business and technical development. Several methodologies are being developed. One of the most interesting is the relevance pattern technique from the use of which may be adduced those gaps in technology which must be overcome if the overall business objective is to be achieved.

As business risks increase, the correct judgement of the
nature and timing of investment commands a premium compared with which all other management decisions are secondary.

As Galbraith has pointed out, the first Ford motor car cost £28,590 to make and eight months to put on the road. In recent years the Ford Mustang cost £39 million and took 3½ years from decision to offer for sale, while the latest Capri has exceeded even these figures.

For such a policy to be effective, the company must have, or have available to it, manufacturing processes capable of rapid adjustment to the new product requirements. The rigidity of mechanized mass production plants is well-known and one of the beneficial aspects of the introduction of automation concepts is the scope which they provide for the development of more flexibility in mass production methods.

Product obsolescence will therefore become part of the total company planning, not so much as a matter of replacement of worn-out or defective parts, but a conscious process of innovation and as a safeguard against the external threat of competitive technologies.

Material Choice

Seventy years ago, silicon—the second most abundant element on the earth—was primarily used as a base material in the manufacture of glass, or as a trace element in steel. Since then the uses of silicon have expanded considerably,
as for instance in the form of silicon chemical compounds - of which some 16000 have been synthesized - or as one of the most widely used materials for semiconductor purposes, or as an engineering material in the form of silicon nitride.

This example, repeated for many other elements, serves to illustrate the ever-widening range whereby materials technology continues to be of fundamental influence in the innovative process.

But there is another aspect of the development of materials technology. As we come to rely increasingly on the development of new materials, we find that the production of these materials is both complex and expensive, so that their supply at competitive prices requires the benefits of scale both in production and in supporting Research and Development services. Materials management will, therefore, become increasingly important not just from the point of view of economy, but as a deliberate part of product policy in switching from one material to another to take advantage of changing supplies.
CHAPTER TEN

CONTROL TECHNIQUES IN INVENTORY MANAGEMENT
Control techniques are the means by which material of the correct quantity and quality is made available as and when required, i.e. based on operational needs, with due regard to economy in storage and ordering costs, purchase prices and working capital. How does a Company determine how much to order? How does a Company determine when to order? This, in fact, is the crux of the problem with any Inventory Management System or Technique. The problem, therefore, is to reach a compromise in some manner so that the total of order costs and carrying costs is as low as possible.

It involves the following processes:

1. Assessing the items to be held in stock.
2. Deciding the extent of stock holding of items individually and collectively.
3. Regulating the input of stock into storehouse.
4. Regulating the issue of stock from the store-house.

Stock is held for the purpose of providing a reservoir of material to absorb the effects of variation in delivery and consumption and to maintain the ready availability of supplies within the organisation.

Reasons for holding stock

Every industrial concern has store houses and finds it necessary to keep stores in stock for one or more of the following reasons:
(1) Delivery cannot be exactly matched with usage day by day.

(2) Discounts or improved prices for bulk purchases more than off-set the cost of storage.

(3) Operational risks or possible changes in programme require the holding of stock as a precaution against serious breakdown or interruption of production or other activities.

(4) The cost of storage is outweighed by the saving in production of quantities in excess of immediate requirements as in the case of piece parts, i.e. production in economic batches.

(5) For work in progress where a completely balanced production flow is impracticable.

(6) For finished products where the holding of a buffer stock between the manufacture and customer is essential.

(7) Owing to fluctuations in the price of a commodity, it is considered desirable to lay in stocks when prices are low.

The extent of stock holding is influenced by four main considerations:

(1) Operational needs.

(2) Time required to obtain delivery/goods.

(3) Availability of capital.

(4) Cost of storage.
Type of stock

There are three types of stock that must be maintained and they are commonly called raw materials, work in progress or process and finished stock. Large companies may have more groups, for instance, work-in-process can be transit - moving from a fabricating plant to an assembly centre. Finished stock may be at plants, in transit or spread all over the country in warehouses, or consignment or in dealers' stocks. The usual company has all three kinds of inventory. It tries to carry enough raw materials to meet foreseeable demands. It has work in process as long as manufacturing continue and it carries some finished stock if only such items as fastening and hardware stores, bought on the outside.

"All three stocks represent money tied up. In reality they are three stages of one stock. The objective of control is to achieve an economical balance between the costs of ownership incurred to avoid customer disappointments on the one hand and on the other, the costs of those disappointments" according to Phil Carroll.

The Basic Elements of Inventory Control

Before one can determine what one's optimum inventory should be, one must know something about the basic behaviour of inventory. The use of highly sophisticated mathematical
techniques for determining safety-stocks, production control, multi-storage inventory-models and simulation, dynamic programming, these do indeed permit an organisation to save large sums of money. But the basic principles of inventory control are simple, and consist of the order-size or economic order quantity (i.e. how much to get at one time), the order-level (i.e. when to buy), the maximum stock, the minimum stock, the safety stock (also called buffer-stock or reserve-stock), the lead-time, or cycle-time, and stock-out costs.

**Order Quantity**

The greater the order quantity, the greater the average inventory. Suppose a Company uses 100 units of an item per week and orders in lots of 200 units whenever it runs out of stock. In this case, its maximum inventory would be 200 units right after a new consignment or shipment is received and its minimum inventory would be 0 units when the stock is used up. Since the usage is steady, its average inventory would be 100 pieces - exactly between the maximum and the minimum.

What happens if the Company doubles its order quantity while usage remains unchanged? Its maximum inventory doubles, there are 400 pieces in stock immediately after a shipment is received. It takes twice as long - four weeks instead of two weeks - to use up the inventory. As a result the
average inventory also is twice as great. It consists of 2 weeks stock, or 200 units, instead of just one week's stock.

**Lead time**

There is always some interval between the time that the need for material is determined and the time the material is actually manufactured and delivered. This period is the lead time. The total lead time has two components, administrative lead time and supplier lead time. Lead time varies as a local supplier is categorized as source of shortest lead-time items as he has materials in stock for immediate delivery. This lead time permits both buyer and supplier in process the order efficiently and economically. Much longer lead times are necessary for items made to order and the more complex the item the longer the lead time. Lead time also vary considerably if the items are imported, largely due to licensing procedures and the lead time prevailing with the foreign suppliers. Lead time also vary for identical items as one supplier may require a greater lead time for a given item than another supplier when the supplier is working at capacity and has a huge order backlog, variations in lead time can be quite substantial. In order to prevent a stockout a company must have an inventory that is at least adequate for usage during the lead-time. Often the lead time changes unexpectedly because of business conditions.
Safety-stocks

If usages and lead times could be predicted exactly, it would be possible to limit maximum inventory of an item to the order quantity. In practice this cannot be done. Suppliers fail to keep delivery promises, usage forecasts are inaccurate and exigencies of business are such that there would be rise and fall in demand. Extra inventory is needed to protect against unreliable forecasts and this extra inventory is called 'safety stock'. Excess safety stocks boost inventory investments; inadequate safety stocks fail to give the desired protection. When forecasts of lead time and usage are accurate, the maximum is equal to the order quantity plus the safety stock, and the minimum inventory is equal to the safety stock. If the usage is steady, the average inventory equals half the order quantity plus the safety stock. But this does not happen in practice as the safety stock is determined by analysing the past pattern of usage which is not necessarily a guarantee for the future pattern of requirements. Nevertheless, safety stock reduces the stock-out risk.

Limitation of Maximum-Minimum Systems

Problem of Demand Change: All inventory Control Systems ultimately get related to the order point or 'Max - Min' systems. Control can be improved and inventory investment reduced through application of ABC systems, selective control
and other techniques. But these systems will have one
fundamental weakness; they work well only when the lead time
and the demand for material during the lead time can be pre-
dicted with reasonable accuracy. Many companies increase
their production to a very great extent in an exceptionally
prosperous year and demand for individual products can
change to such an extent, the upward surge can easily upset
all the calculations and no regulated pattern can be
established from such spasmodic rise.

Let us assume that an item normally has a usage of 1000
units during its one-month lead-time period and that the
previous years usage pattern indicates a safety stock of 250
units to be more than adequate. If demand rises by 50 per
cent during the year, as is often the case when business is
increasing, lead times lengthen too and a whole series
of stockout is possible. The first stockout will come
when usage during the lead time is 25 per cent greater than
normal. The inventory planner say consider usage abnormal
and not increase safety stocks after this first stock-out.

A second stock-out will almost certainly touch off an
analysis of the item's usage. Usually order point will
be increased. Suppose that the item that used to have an
average usage of 1000 units a month has these usages for
six months; 1030; 1100; 1400; 1250; 1300 and 1400. The
planner notes that the average usage during this six months
period was 1250 units. He also notes that maximum usage was 1400 units. He may increase the order point to 1500 units, giving him a safety stock of about 250 units if lead time usage continues to average 1250 units.

If demand continues to rise, the inevitable result is another stockout. If the Company is controlling thousands of different items with a simple max-min system, it will be plagued with stockouts. Eventually, however, order points and safety stocks are increased to the point where inventories are more than adequate to cope up with peak demand. And, in fact, it is probable that they will be increased well beyond this point. In a period of rising demand, inventory planners are subject to almost daily harassment from production and sales executives because of shortages and stockouts. On the other hand, there will be few immediate complaints if they raise order points and safety stocks to the point where stockouts are highly unlikely regardless of how much usage increases. Consequently planners not only boost order points to meet present demand but also allow for future growth of demand.

For example, an item that once had an order point of 1250 units and a safety stock of 250 might wind up with an order point of 2000 units and a safety stock of 500, even though record consumption might not exceed 1800 units.
Eventually planners would attempt to anticipate increased demand and build up stocks ahead of usage.

If this increase in demand is temporary, the results would be very expensive and detrimental to the interests of the firm as money tied up in dead inventory or slow moving would be colossal. Suppose, for example, that on account of business depression or some other cause the Company's usages dropped well below its old norm of 1000 units to 700 units a month. In such a case, its investment in inventories would initially be at least three times greater than necessary, and would continue to be substantially excessive until max-min quantities were gradually adjusted back to the old levels.

Basic weakness of Max-Min

Few companies experience such a stable demand for materials that they can rely entirely on a max-min perpetual inventory control system such as that described above because of the following weaknesses:

1. Stock levels are actually set by clerks, since managers do not have the time to study inventory levels of individual items.

2. Reorder points and safety stocks often are not changed for years on end.

3. Delay in posting records makes them useless for control. Reorder of a critical item can be held
up until the clerk gets around the posting the last withdrawal, indicating that the re-order point has been reached.

For the reasons given above, many Companies do not use max-min or order-point systems to control inventories of their most important materials. Instead, they use periodic re-ordering system. In periodic re-ordering, the inventories are regulated by the quantity ordered and the period between order is fixed. In other words orders are placed at regular intervals for amounts needed to bring stocks up to the desired level.

Application

Periodic re-ordering is commonly used when one or more of the following conditions prevail:

1. The item is ordered frequently and expenditures for it are sufficient to warrant tight control.
2. Inventory balances are determined only periodically, making an order point system impractical.
3. Many items are ordered from the same suppliers and ordering jointly reduce price, transportation or paper work.
4. Usage is discreet or irregular. For example, an item may be withdrawn from stock just one day in a month.
(5) The item is purchased in large quantities and requires a substantial percentage of a supplier's capacity.

(6) Either price does not vary with quantity purchased or quantity discounts are available even though an order is scheduled for partial shipments.

Periodic reordering is used almost always by Companies that make a limited product line in large quantities. It is widely used to control production parts inventories in the automobile and appliance industries. In those industries, where identical products are finished on assembly lines day after day, inventory management is regarded as the regulation of a flow of parts and materials. It is not thought of as a series of addition to and withdrawals from stock as it is in job-lot system or perpetual inventory systems used for more production material.

There are various useful conceptional techniques developed in the last 20 years which could be termed largely as mathematical techniques, in the management of varied problems of inventory controls.
The Varied Statistical Quality Control Techniques

1. **ABC analysis**

   The technique of ABC analysis is nothing but the act of fixing rough priorities. In other words ABC analysis is the act of separating the significant few from the comparatively unimportant many. Note that the value is defined in terms of financial worth of the quantity consumed annually or in terms of the value of the quantity in stock, and not in terms of unit price of the item. Cotton would be a value to a textile mill, while the platinum bottle in its laboratory would be a C value item. This Control Technique is explained in greater depth towards the close of this Chapter.

2. **Queueing theory**

   A queue consists of customers waiting for some sort of service from some provider of that service which is at that moment occupied. It is not necessary for customers to wait in an actual geographical line or in the order in which they will be served.

   A queue builds up for two reasons:

   (i) The rate of output of the service facility is constant, but the rate of input varies in a random manner. This causes terrible queue, even if the average service rate is greater than the average arrival rate. Consider an example of a petrol pump. Cars do arrive at fixed intervals.
Sometimes, for many minutes at a stretch, there will be no cars at the pump; at other times, several cars arrive almost within seconds of each other, and there is a queue; and all the cars will not want the same thing and so the time taken to service them will differ.

(ii) The average service rate is less than the average arrival rate. Suppose that the service facility can handle ten customers per hour on the average, but that eleven customers come per hour on the average. Then, an infinite queue will build up, unless the service rate of the existing service facility is improved.

It costs money to provide service facilities. So they should not necessarily remain idle. On the other hand, it costs money if the customers are turned away, even if the customers are one's own mechanics, machines or materials.

Is the service facility adequate? This is the first question that will spring to the mind of the person who has to make the decision. A common-sense solution appears to be to see whether the average service rate is greater than the average arrival rate.

Queueing theory through its formulae can also give various other useful information, such as -
1. The average number of customers queueing in the system.
2. The chances in percentage terms of there being more than any given number in the queue.
3. Average waiting time per customer in the queue.
4. The number of customers who will have to wait more than any given length of time.
5. And finally, the effect on each one of the above from any given increase in the service facility or service rate.

Queueing theory is an extremely sophisticated statistical technique and can give valuable answers even when the arrival pattern cannot in any way be influenced by the service facility. Queueing theory reflects an attitude of mind. It can, therefore, be applied in the most unexpected places. You may find that the optimum state of affairs is to tolerate a certain maximum wait for a certain (and long) length of time if they wish to get served. So even a super-market will find it more economic to loose a certain number of customers than to provide the extra-facilities required for serving every customer without delay. Or, on the contrary, a slight extra expenditure may permit one to serve very many more extra customers.

3. Simulation:

Simulation is being used in India with increasing frequency to make better decision in the areas as diverse
as maintenance, scheduling, inventory, the optimum number of staff for certain jobs etc. It is cheap and is easy too. It is the best technique to use in those cases when the available data is not complete enough or orderly enough to permit the use of other techniques.

Simulation consists of using actual past data to form a mathematical model of situation, and then using the theory of probability to extrapolate, i.e. to imitate the behaviour of model under various conditions. Past or present events are knowable and measurable. In those cases where the future is likely to resemble the past or the present, simulation can predict the future by using the theory of Probability.

Simulation, under its code name of 'Monte Carlo', enabled scientists to find out when and how an Atom Bomb was likely to explode without the expense of trying to explode one.

Simulation cannot predict how the demand will fluctuate period by period i.e. calendar week by calendar week. So we will have to stock the same number of units for every period. And whatever be the number we stock, they will exceed or fall short of the demand during most of the periods. We must, therefore, choose that quantity which will be the most economic result in the long run.
When we say that the future will resemble the past we mean that the general pattern detected in the past will continue into the future, but it will not be identical in the short run. Using this premise, we will now simulate the future pattern of demand and then we shall see how the stocking of different quantities will affect the overall cost. Note the forecast will not prove accurate, period by period; but over a large number of periods, simulation does give the optimal answer.

4. **Linear Programming**

This is being increasingly used in India for problems as diverse as distribution, transportation, production, the selection of suppliers, the optimum utilisation of foreign exchange; in short, for the optimum utilisation or allocation of any resource such as men, materials, machines and equipment, money and to minimise the idle time of or the distance travelled by any of the resources. Here costs can be reduced without making any changes whatever in design, price or number of items carried in inventory. As the term implies, linear programming can be applied to any problem in which the mathematical relationships are linear (i.e. in algebraic terminology, $a + b = c$). Typical are problems with these characteristics:
1. One plan of action must be selected from many possible plans. For example, which of 200 parts used in the product should be manufactured and which should be sub-contracted.

2. The objective is to maximise or minimise a critical factor, such as to minimise the cost of buying.

3. Relationships in the quantities are linear. This means, for example, that it costs ten times as much to buy ten gallons of paint as it does to buy one gallon.

4. The resources you can use in achieving your objective are limited. Perhaps the amount of steel you can buy in any one month is limited by your storage capacity.

In materials management, the most popular application has been in transportation. Many large companies buy material from several suppliers that is shipped to several plants. In considering how business is to be divided, they must take into account not only the price charged by each supplier but also the cost of shipping the material to each plant.

5. Learning Curves:

The assumption behind a learning curve is that as one learns to do anything repetitive one tends to do it better,
and, therefore, in Industry, at lesser cost.

Many items, some quite sophisticated technologically, are being produced in India for the first time. The buyer may be convinced that the price is excessive. But he almost invariably lacks the data necessary for cost-analysis, and his technical departments will rarely find it possible to spend time duplicating the supplier's process of learning. A skillful buyer may succeed in negotiating certain concessions even from monopolistic suppliers. But such changes will generally be the result of changes only in the quantity or in the specifications. The costs reduced by 'learning' will not figure in the negotiations, as the buyer does not have any data, and the supplier will cite 'actual experience' in defence of his price. "Actual experience" merely means that the supplier will in his new proposal include the man-hours which were required on his previous jobs; and he knows much more about his manufacturing details than the buyer does, the case for the 'defence' will be much stronger than that for the 'prosecution'.

This is where the learning curve can help him greatly. The learning curve should be applied by the buyer to any item the production cost of which is likely to fall sharply as a result of the experience gained in making it. The learning curve provides a buyer with logical figures which show what the real cost ought roughly to be. It is
assumed that the supplier will reduce his price, or offer some other advantage, if he knows that the buyer is aware of the real profit margin. So a skilled negotiator can reduce his supply-cost by using the Learning Curve. The learning curve is a tool for the negotiator. He must, therefore, first of all convince the suppliers he faces of the validity of a Learning Curve.

6. **Decision Matrices**:

This simple system helps one to make the best selection when confronted by several alternatives, each one of which contains various desired attributes in varying proportions.

When you buy something, you will consider, besides price, several factors like quality, proximity of the supplier, after sales service etc. All suppliers are not identical in all these respects. There are a bewildering number of combinations as each supplier is better or worse than every other in so far as every desideration is concerned.

The matrix system depends fully on an evaluation based solely on your experience and your judgement, but unlike your normal system, does not contain the underlying premise that you be a mathematical genius. This system is purely subjective in that only you can decide what weightage to give each desideration and in that only you can state how well each supplier rates against each desideration. The common-sense way expects you to do simultaneously five
rather incompatible things:

1. To remember all the desiderata and their weightages.
2. To evaluate the performance of each supplier against each desiderata.
3. To rate each supplier for each desiderate by multiplying by the weightage the results of each evaluation.
4. To remember each such rating.
5. To work out the final rating of each supplier.

All that a decision matrix does is to put things down on paper. It gives you the full benefit of 'judgement' which is subjective, while minimizing the irrational sub-conscious component of any subjective choice.
Application of Value Analysis: Explanation of ABC analysis

Value Engineering and Value Analysis - Value engineering and value analysis are close to the same thing. They are approaches to cost saving that deal with product design. "Value engineering" usually refers to what engineers are doing in this direction while "value analysis" is more likely to refer to the work that the purchasing department does in this area.

Value engineering or value analysis means that you regard everything you make or buy as being made or bought to serve a purpose. Before making or buying any equipment or materials, engineers and buyers study what purpose these things serve. Would other, lower cost designs work as well? Could another less costly item fill the need? Will less expensive material do the job? Are the vendor's cost as low as they ought to be?

Engineers who raise such questions decide answers. The purchasing department, however, does not decide answers. It raises questions and consults with the engineering department and with the cost accounting department.

Both engineers and purchasing men should also watch the specifications. In one plant the purchasing agent found that its engineers had specified parts to be made to close fits - but then they were enamelled before they were used! That destroyed any close fit. Loosening the
the tolerance cut the purchase price. Before that the company was not getting value for its money. It was paying for a close fit that it did not need.

Of course you do not get those savings free of cost. Whether you use the task-force or the permanent-department approach, it takes time and effort to cut such costs. But value analysis, intelligently done should produce savings of many times its cost.

Value analysis as done by the purchasing department sometimes creates internal frictions because buyers are venturous souls who are all too ready to set up their ideas of quality against those of engineers. Perhaps you should expect this if you keep buyers under pressure to buy cheaper, and perhaps this is good. Buyers and engineers should work together toward the common goal—lower costs.

Value analysis tries to reduce the costs of Purchased Materials by studying the purpose to be served by a part or component being bought, and seeing if there are other less costly ways for accomplishing this purpose. Although the purchasing department is almost always active in this work, value analysis is encompassed in the somewhat large subject of value engineering which we took up in connection with cost control on.
'A', 'B', 'C' Analysis

Big companies have to stock and keep track of 50,000 or more different items. Controlling these inventories takes hundreds of clerks, whose salaries run into hundreds of thousands of dollars.

Yet one purpose of inventory control is to control with the least clerical cost. Some factory items are like paper clips and rubber bands in the office. They are not worth keeping records of. Just keep a supply of such items on hand and let people help themselves. When the supply gets low, order more in spite of the probability that uncontrolled materials will be used wastefully. This does not matter for little things; it is cheaper to stand the loss than to keep the records.

On the other hand, you cannot just carry plenty of everything and let people help themselves to everything. So you have to decide which items should be closely controlled. Look over your stock records, item by item. Classify them into "A", "B" and "C". 'A' items are the big investment items - the vital few. 'A' items get the full record-keeping treatment. Calculate their needs ahead of time according to period of use, and schedule their manufacture of purchase so that they arrive just before you need them. Order them few and often. Hold their inventories as low as possible. Let men help themselves to these items, using no requisitions, but watch the inventory levels very carefully.
'B' items get middle treatment. They are less important than 'A' items but are worth keeping careful records of their use. Use minimum-maximum controls. Rely on past usage and set minimum stock limits and standard re-order quantities. Whenever the stock of an item gets down to the re-order point, have this trigger a replenishment order of a standard quantity. Issue such items from the stock room in exchange for written requisitions (25% of the items carried 10% of value).

'C' items are the wasters, the trivial many. Give 'C' items short shrift on planning and records. Just order plenty of cotter pins, washers, solder, and the like. Use some kind of a bin minimum or "last container" arrangement. To trigger re-orders tie up the re-order point quantity in a sack or put a cardboard on top of the re-order quantity in the bin. Then re-order enough to last a while. Put these items at the operatives' work-places where they can help themselves without using requisitions. Do not calculate future needs of 'C' items. Do not even price them to products individually. Charge them to an over-head account.
<table>
<thead>
<tr>
<th>Classifications</th>
<th>Close Control</th>
<th>Moderate Control</th>
<th>Loose Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Based on calculated requirements</td>
<td>Based on past usage</td>
<td>When supply gets low order more</td>
</tr>
<tr>
<td></td>
<td>Keep records of receipts and use</td>
<td>Keep records of receipts and use</td>
<td>No records</td>
</tr>
<tr>
<td></td>
<td>Close check on schedule revisions</td>
<td>Some check on changes in needs</td>
<td>No check against needs</td>
</tr>
<tr>
<td></td>
<td>Continual expediting</td>
<td>Expediting for prospective shortages</td>
<td>No expediting</td>
</tr>
<tr>
<td></td>
<td>Low safety stocks: (under 2 weeks)</td>
<td>Larger safety stocks: (up to 2-3 months)</td>
<td>Long safety stocks: (2-3 months or more)</td>
</tr>
</tbody>
</table>

The accompanying chart illustrates graphically the concept of ABC analysis.
A-B-C-ANALYSIS

Percentage of value

11 items include 8% of total items but 75% of value.

11 items include 26% but 19% of value.

1C items include 66% of items but 6% of value.
Pert Planning and Scheduling and Control:

Fundamentally PERT is a technique of project management useful in the basic managerial functions of planning, scheduling and control. The planning phase of any venture involves a listing of tasks or jobs that must be performed to bring about the venture's completion. Cross requirements for material, equipment and man-power are also determined in this phase, and estimates of costs and durations for the various jobs are made. Scheduling, on the other hand, is the laying out of the actual jobs of the project in the time order in which they have to be performed. Man-power and material requirements needed at each stage of production are calculated, along with the expected completion time of each of the jobs. Control, generally regarded as "the underlying managerial function", begins with reviewing the difference between the schedule and actual performance once the project has begun. The analysis and correction of this difference forms the basic aspect of control.

As stated at the outset, PERT is useful in all three functions - planning, scheduling and control.

PERT advantage:

More than any other technique PERT gives you some degree of control over difficult-to-estimate projects and over projects which are surrounded by considerable
technological uncertainty. By forcing you to think of the parts of the whole and how they link together, PERT forces you into making time and cost estimates for individual parts of the whole. Doing this seems to produce greater overall accuracy.

PERT also helps stop the "crash-everything" attitude. It also avoids frequent lengthy meetings needed for coordination. And it cuts down on cross-checking of unrelated projects.

Another PERT contribution is the help it gives in detecting trouble while you are still in the planning stage. By summing up the times of the several chains of activities, PERT shows even before you start which chains of activities will take the longest time and which, therefore, need the most attention so they would not hold up other activities. Almost always a bottleneck path of activities can be speeded along, on a crash-programme basis, if necessary, so the whole project can move faster.

PERT also sets up progress check points. As reports of work done come in, they are fed into a computer which compares the progress of each activity with its planned progress. If any chain of activities is falling behind (if there is any "slippage"), PERT shows it up. You find out about slippages right away before very much harm to the programme has been done.
Still another advantage of PERT is that you can use it to simulate certain conditions and then see how the whole net-work would be affected if less or more time were spent on certain activities.

PERT has the peculiar characteristic (which can be bad as well as good) of being self-validating to some extent. Because you have all the subsidiary event dates, you work toward them and so meet them.

**PERT disadvantages:**

Some Managers resist PERT because they see it as taking away part of their jobs. Construction superintendents like to be the fountain heads of all knowledge about how long work will take and how the delay of one activity might affect the whole activity. And it is true that when you PERT a job and do it on a computer, you take away part of some man's work. When PERT is first introduced the resistance it meets (almost sabotage) sometimes makes it almost useless. Most companies report that such opposition disappears soon but there may be losses at first from using PERT.

Some people find fault with PERT's use of three time values. Indeed, some companies do not use three time values at all. They use the "most likely" time only. They say that the most likely time sought to be what it says. With only one time, men aim toward it and try hard to meet
Another objection to PERT is that almost always pessimistic times vary from the most likely time more than do optimistic times. The weighted average is, therefore, always a longer time than the most likely time, and this puts unintended and unwanted slack into all calculations.

Some critics of PERT do not like it because it forces men to estimate times for activities. They say that when you press men to make estimates they will put in a fudge factor and that all time estimates will be too liberal. If this happens, none of the ensuing calculations rectify the inaccuracies. Worse yet, liberal estimates will make people work toward minimum performance (since that is all the programme calls for) and not anything better. Perhaps this objection has more validity for PERT/time than for PERT/cost because over liberal cost estimates boost bid prices and lose contracts.

Still another objection to PERT is the cost of reviewing all the figures every week or so to see where you stand. PERT can help only when it is up-to-date and this means frequent computer reviews of the data at considerable cost.

There are still other objections to PERT but a good many of them are really more complaints that it is not perfect than that it is bad. PERT does not, for example, tell you if you have the resources the project will need. Nor does it tell you if the project will need the same
resources for different activities at the same time. And
PERT does not tell you if resources are interchangeable.

PERT makes it look like things have to be done in
sequence when in fact they can sometimes be overlapped or
done in parallel. You do not always have to complete one
activity before you can start the next one. And after
projects get under way, PERT shows up delays but it does
not tell you anything about causes. And it does not even
show up delays until activities are supposed to have been
completed.

PERT does not give you a level work schedule because
it pays no attention to the work load it creates in relation
to departmental capacities and to work loads caused by
other jobs. PERT does not work so well if you change the
priorities of different projects very much. Nor does it
solve the problem of low priority jobs getting pushed back
forever.

PERT is limited in the detail that you can afford
to go into. Rarely would you try to chart minor details
that take only hours or days. So you do not PERT every-
thing. Nor do you up-to-date charts all of the time.
You just cannot afford to be making new big charts fre-
quently.
Application of Sophisticated Tools of Planning & Control:

Computers:

Speed is the outstanding characteristic of the Computer Electronic Data Processing (EDP) Machines which are much faster than mechanical ones, whose speed is restricted by inertia. Electronic ones can do over 3 million calculations per second, so that a rupee's worth of computer-time will buy several hundred man-years of manual calculations. Such speed is essential for many scientific purposes, which often require billions of calculations, generally based on a small quantity of data. Industrial problems require the processing of vast quantities of data, but comparatively few calculations.

A few organisations in India use electronic computers for accounting jobs, such as making out the pay roll. Fewer still use computers for inventory control, production-planning or production control. A computer cannot answer general questions and few organisations know enough about most of their operations to be able to formulate questions on the basis of precisely quantified and properly organised data.

When are computers useful?

1. If you produce over 6 items, they can help with process planning and production control.
2. For net-work analysis, if there are over 400 events.
3. For design analysis.
4. For linear programming and for simulation.
5. For inventory control and accounting.

**Net-work techniques:**

The net-work techniques provide the finest of
Managerial Controls:

(a) Whenever a project/activity is complex,
(b) Whenever time is money, and
(c) Especially for projects which are not identical to any previous ones.

Net-work techniques can reduce the gestation-period and can be used for projects as varied as preparing balance sheets or marketing campaigns.

There are two net-work systems that we normally come across. PERT (Programme Evaluation and Review Technique) and CPM (Critical Path Method). There are other techniques as well such as RAMPs (Review Analysis of Multiple Projects) and LOB (Line of Balance) in the family of Net-work Analysis Techniques.

Basically, the net work analysis technique consist of:

1. Planning.
2. Sequencing.
3. Scheduling.
5. Locating the critical paths.
6. Allocating resources.
7. Evaluation and review of the critical path.
8. Revision.

Steps 3 to 8 are done 'de novo' whenever conditions change. This enables one quickly:

1. To know whether a change is significant, and
2. To forecast the effect of such a change on the project as a whole.

These techniques minimise completion time, and maximise the utilisation of resources. They give a comprehensive map of the whole picture; yet they easily isolate any desired activity, and show its position; and by automatically pin-pointing trouble-spots before they arise, permit timely action.

**Line of Balance (LOB):**

The LOB VARIANT OF PERT is helpful when you are making a considerable number of one kind of complex product. If you are making 50 cars, for example, and they are to come off the line once a week beginning six months after the first assembly work starts, then major component parts need to be coming to the final assembly line at the same rate as their usage.

LOB charts show the summation of such components finished or passing through certain control points as they
move toward completion. In Figure given on next page, the LOB line shows the numbers of various components which should be finished, or are past given control points. The vertical bars, one for each component, show how the parts progress matches up with their schedule. All bars below the LOB line are behind schedule. Those above are ahead. Such charts make it easy to see which components are lagging and so need pushing.