

1. INTRODUCTION

We will be shouldering the responsibilities of executive of tomorrow so it is to understand methods, plans, various techniques that are essential to operate the effectively and efficiently. For this purpose we must have the knowledge of PPC.

This is also true that this subject intervene into many departments of industrial organization, their relations with these departments are explained in first few topics.

This basic objective of creating the manufacturing organization is to make the products. Thus the production is the nucleus or the centre of entire business operations. It must be emphasized, however, that on signal system of forecasting, preplanning, planning and control is suited to all industrial enterprises, no matter how well it may meet the needs of this on that special company. PPC functions look after the manufacturing activities.

PPC comprise the planning, routing, dispatching in the manufacturing process so that the movement of material, performance of machines and operation of labour however are subdivided and are directed and coordinated as to quantity, quality, time and place. Planning and control are two basic and interrelated managerial functions. They are so interrelated that they can be and often are considered as being one function. Planning is the preparation activity while control is the post-operation function. Both of them are so closely related that they are treated as Siamese twins. Planning sets the objectives, goals, targets on the basis of available resources with their given constraints. Control is the integral part of effective planning. Similarly control involves assessment of the performance, such assessment can be made effectively only when some standard of are set in advance. Planning involves setting up to such standard. The controlling is made by comparing the actual performance with these present standard and deviations are ascertained and analyzed.

Production is an organised activity of converting raw materials into useful products but before starting that work of actual production, production planning is done in order to anticipated possible difficulties and decide in advance as to how the production should be carried out in the best and economical way.

Since mere planning of production is not only sufficient, hence management takes all possible steps to see that project or plan chalked by the planning department are properly adhered to and the standards set are attained in order to achieve it, control over production is exercised. The aim of production control is to produce the products of right quality, in right quantity at the right time by using the best and least expensive methods.

PPC thus defines as the process of planning the production in advance, setting the exact route of each item give “production order” to shops and lastly to follows up of progress of produces according to order. The principles of PPC gives in the statement, “First plan your work, then work your plan”.

There are few other department associated with PPC are personnel department, manpower planning, costing department etc. Design department is important one as “ The design is the problem of anticipating or trying to do what will be required in future and improving what is being already produced.

1.2 PREPLANNING, PLANNING & CONTROL

The activities of preplanning, planning and control may be considered to take place in a time sequence. The preplanning is completed before production commences. Planning takes place immediately before production starts and control is exercised during production.

Preplanning :

It is the procedure followed in developing and designing a work or production of a developing and installing a proper layout or tools. It may be involved many functions of the organization and draws upon forecasting, product design, jigs and tool design, machine selection and estimating to enable proper design to be made. In short, preplanning decides what shall be made and how it shall be made.

In respective manufacture a large uneconomic output could be produced if preplanning is omitted. It is also important in one of the operations such as setting up a new plants as preplanning can identify and avoid probable costly errors.

Planning :

This stage decides where and when the product shall be made. It includes the sequencing of operations viz outing and the time schedule for manufacturing viz scheduling. It also states procedures for material planning and supplies, machine loading and deliveries. To perform as functions properly it will need past records of performance and to control statistic which may be obtained from pre-planning, cost control or progress.

Control :

This refers to the stage of ensuring that the planned action is in tact carried out. Control initiate the plan at the right time using dispatching and there after control makes appropriate adjustments through progressing to take care of any unforeseen circumstances

that might arise. It includes measurement of actual results, comparison of the same with the planned action and feeding back information the planning stage to make any adjustments required. The pattern of control is seen in material control, machine utilization, labour control, cost control and quality control.

1.3 PROJECT PLANNING OR PREPLANNING :

Before starting every project its planning is done. Planning a project is a very important task and should be taken up with great care as the efficiency of the whole project largely depends upon its planning. While planning a project each and every detail should be worked out in anticipation and should be considered carefully considering all the relevant provisions in advance. Project planning consists of the following important steps.

1) Market Survey :

Market survey in a broad sense, is a commercial survey for the suitability of business it provides necessary statistics helpful for forecasting planning project.

2) Project Capacity :

Capacity of the project must be decided considering the amount of money which can be invested for particular type of product and how the money which can be invested for a particular type of product and how the money can be arranged. While deciding the capacity of the project, following factors must be considered.

- i) Demand of the product in the market.
- ii) Quantity of power, water, land and raw material available.
- iii) Nature of product.
- iv) investment capacity.

3) Selection of Site :

While selecting the site, technical, commercial and financial aspects should thoroughly be considered. Site should be selected in two states; in first stage general location for factory should be selected in this location. Important factors to be considered for the selection of site.

- i) General location of the factory.
- ii) Selection of exact site.

4) Plant Layout :

One of the most important aspects of production system design is layout of facilities primary object of these is to optimize the arrangements “ 4 m’s” and supporting services.

5) Design and Drawing :

After deciding the product its detailed drawing are prepared so that no doubt is left for future. Detailed specifications for raw materials and finished product should be decided carefully along with the specification of the machines required for their manufacture.

6) Material requirement :

The list of materials required for manufacture is prepared from the engineering drawings. This list is known as “Bill of materials” part list”.

7) Operation Planning :

Work of this is to select the best method of manufacturing, so that the wastage of material, labour, machine and time can be eliminated, to have more production with less fatigue. This work is done in two phases, namely. Method study is conducted to eliminate the wastage due to ill directed and inefficient motions. Time study is the exact estimation of time and is very essential for correct pricing.

8) Machine loading :

Number of machines to be installed in a plant should be decided very carefully while planning, proper care should be taken to find out the machining time for each operation as correct as possible, so that arrangement for full utilization of machines can be made and machines loading program is prepared accordingly.

9) Sub-contract consideration :

With the development of technology and specialization, it is difficult to manufacture all the components in the same factory, due to fact that specialized machines plants and workers.

The decision about particular item, whether to purchase or to manufacture, is taken by planning department after making a through study of the relative merits and demerits.

10) Equipment Requirement :

After knowing the number of equipments, their accessories and tools required, cost data can be collected to give an idea of capital requirement.

11) Organisational Layout and staff Requirement :

Layout of organisation is decided by considering the nature of work, type of industry size of industry, etc and in line of above the stalls are appointed.

12) Material Handling :

The material handling problems must be studied before the erection of the factory building and plant layout.

13) Budgeting :

Budgeting is forecasting and preplanning for a particular future period using past experience and market trends.

14) Cost Calculation

Total cost of a product is calculated by adding the expenses incurred during the period on a product.

15) Procurement of Finance :

Generally large industries manage their block capital through partners and shareholders. While the working capital arranged through 'shares debentures, loans and banks.

16) Critical Report on Feasibility :

Generally, rate of return on the invested capital is taken as the criteria for analysing the feasibility of the project.

1.4 PLANNING

Planning is exercise of intelligent anticipation in order to establish how an objective can be achieved, or a need fulfilled, in circumstances which are invariable restrictive.

Planning provides the supporting arithmetic for an objective which has already been decided. It does not establish whether the objective is right or wrong, good or bad, worthwhile or worthless except in terms which have also been decided beforehand. Consequently, only plan is invariably biased in favour of the chosen objective. Incidentally, to attack it on this count is rather like shooting the plainest and setting fire to the plans, not because the plainest is playing badly or the plans are out of the tune, but simply because one does not like the music which is being played.

Planning is an act of prediction, the accuracy of which varies enormously depending upon the kind of objective, kind of circumstances, the skill of the planner and his techniques and chance.

Planning is necessary because resources are limited. Production planning activities originate at the aggregate level and consider decisions relevant to a specific planning horizon. A planning horizon can be a period as short as four weeks a month, or a quarter (03 weeks) but more commonly refers to periods of from six months to a year or more.

The aggregate planning problem is to determine the production rate which satisfies the anticipated output requirements; while minimizing the related costs associated with the fluctuation of work force, inventories, and other relevant decision variables such as overtime hours subcontracting and capacity utilization. Production planning translated sales forecast into master production schedules. There are three distinct types of production planning:

- i) Project planning.

- ii) Lot or batch planning.
- iii) Progressive of continuous planning.

1.5 THE CONCEPTS OF PRODUCTION PLANNING AND SCHEDULING

The concept of production planning is probably best defined by reversion that to read “The planning of production”. As used here, it refers to the establishment of policies, procedures, and facilities for manufacturing operations to produce product required for future. It is ultimately tied to both capacity planning and product determination in which products will be produced and in what quantities and is future oriented. It looks ahead ensure that the inputs consists not only of machinery and raw materials but of people skills, control systems funds and various types of inventories. In essence, production planning make sure that everything is available on time to meet the production target manufacturing system is circumscribed by various limiting factors such market price quality delivery requirements, funds availability and inherent product restrictions like process time or special storage requirements. Planning must take these into account so as to ensure task performance with both limitations and objectives.

Scheduling, on the other hand, is more specific and less oriented to the future scheduling accepts current conditions like available machinery, manpower and material etc on provides as detailed pots for utilizing there facilities to achieve immediate product objectives. A scheduling starts with the desired end results and provides BLUE-PRO for accomplishing the task on hand. Schedules may be as specific as time and cost per. They may outline general steps needed to complete a task or they may lay down specific operations, starts times completion times etc. Often the more specific a schedule is the better it can be used as a production control device.

It is important to note that the division between planning, scheduling an control is artificial. Much of the value of production plans and scheduled are lost if procedures do not exist to provide information feedback, how well are plans functioning? How well as the schedules being adhered to ? These are important inputs, not just because they permit measurement of planning and scheduling abilities, but also because they provide cards warning of deviations and permit corrective action at early stages. They also provide useful managerial developments tools and valuable information for future planning efforts.

The inventory control is the related aspect under production control, through inventors control is a complex attain involving both cost and the use of certain important

concept and techniques. The amount inventory on hand will affect production plans as well as customers delivery and the form of inventory like raw or finished material, and the good at various stages of processing.

It is readily apparent the need for adequate production planning, especially in situation where long lead time are required to change production capabilities. Requirement of rare work force skills of imported equipment or raw materials of expanded plants of facilities can often severally reduce a companies, abilities to meet changing market condition considerable advance planning is done, a manufacturing limitation and it self was insufficient productive capabilities or with an over supply of absolute limited goods.

1.6 PRODUCTION

Implementation is the stage of the project when the theoretical design is turned in to working system.

Implementation phase involves the staff of user departments carrying out specific tasks which require supervision and control to critical schedules.

Production is the process by which goods and services are created. Production systems combine materials, labours, and capital resources in an organised way with the objective of producing some goods or service. Production system may occur in factories, banks, stores, hospitals etc. In all instances, some input to the system is being processed within the system to produce a goods or services as an output; we are in fact dealing with the operations phases of any enterprise.

‘Creation’ of goods and services of production, to perform this function, the production system require inputs from other subsystems of the organization, such as service inputs (e.g. maintenance, supervision, plant layout, design etc.) and control inputs (e.g. measurement, data processing, planning, control, order and sales information processing, forecasting etc.).

Three main factors may be said to determine the place of production planning and control in an organization.

1. The type of production i.e. the quantities of finished products and the regularity of manufacture.
2. Size of the plant.
3. The type of industry i.e. the field of specialization of the plant.

Industries can be classified into types by several methods; by availability of different kinds of labour in different geographical locations, by the demand for different grades of skills, and by the factors relating to investment policy.

1.7 THE MAIN OBJECTIVES OF PRODUCTION PLANNING

1. To determine capacity of all manufacturing departments and to plan systematically coordinated and related production activities within the scope of the enterprise to meet sales requirements.
2. To translate orders received from sales department into orders on the works department and to ensure steady plans of production activities.
3. To find ways and means through which product manufacturing requirements such as materials and their necessary constituents such may be available in right quality and quantity at the right time.
4. To coordinate a number of different department groups so that a fine balance of activities may be maintained.
5. To promote fuller utilization of plants.
6. To assist labour towards right and greater earnings.
7. To train staff in the effective performance of their duties.

1.8 CONTROL

The principles of control are the same for production control, quality control, budgetary control, cost control and other managerial controls. The basic cycle of events in the control are Action, Feedback, Evaluation and Adjustment. Since these events are dynamically in continuous they take the form of a closed-loop circuit. There are seven essential steps in the establishment and application of operating controls. These steps will be discussed in their normal sequence and is diagrammatically represented in figure 1.1.

(A) Operation :

The first step in the control cycle is operation. In this step, the act of doing something, some faults will be obvious and, therefore, easily corrected. Other faults will be more deceptively concealed requiring the steps that follow to reveal them so that they can be dealt with.

(B) Measurement :

The second step is so measure what is being done. In the field of quality control for example, variations in physical, chemical, electrical, dimensional and other properties are measured. In production control, all operations are measured to determine the time required for their performance and the capacities of equipment with which work is done. In

automatic electronic and mechanical operations must be measured accurately in terms of milliseconds before a whole system can be integrated.

(C) Capability Studies :

Analysis of measurements in step two, aided by many reliable statistical technique gives an accurate projection of what actually can be done.

In production control we need to know quality process capabilities so that scrap and defer losses can be figured. Studies of process capabilities tell us what we can do.

(D) Objectives :

After we discover what we can do, we are ready to figure out what we should as this may either be more or less than our capabilities. This decision then leads to plans for using excess capabilities on other plans to increase capabilities either for quality or quantity so that the objective can be met.

(E) Evaluations :

As the information is fed back from operations, it is compared with plans and objectives other evaluations are used to adjust budgets and costs.

(F) Adjustment :

The last step in production control is adjustment. Production control adjustments are complicated because they often require increasing or reducing quantities based upon past operation and sales in quality control adjustments are made to maintain product quality requirement within limits.

The figure 1.1 illustrates the best cycle in control of production. In it, image two rotating sequence on the basic elements of action, feedback and evaluation that come logure in compound adjustment. This is based on the current information.

(G) Feedback & Flexibility :

It we shoot at the target but cannot tell how close to the balls eye or bullet hits out next shot is likely to be no better than first. But if we do know where the first shot has hit, we can adjust the aim for next one and thus improve our marksmanship. Information received after the performance of an action in time to be used as the basis for future, performance is known as feedback, it is the vital control.

The keys to successful plant implementation are feedback and flexibility. Information must be provided to measure actual progress against the planned and when discrepancies exist, the manufacturing enterprise must be flexible enough to shift, if necessary. This implies the establishment of details, benchmarks during the planned period. Measures of progress, explicit statements concerning the assumptions made about the operating environment and a formal procedure for analyzing the process.

“Doubling production within two years” is not a plan. It is a goal. The plan must indicate how this will be done, when the various steps will begin and be completed and what assumption underlines the plan and goal. As the plan is being implemented, frequent checks are required to determine whether or not things are proceeding on schedule e.g. ordering of machinery, training of new workers, behaviour of market. The cause behind any discrepancies must be examined. Only then we will know whether to speed up or slow down present rate or progress or a shift is required ?

1.9 WHAT IS FUNCTIONS OF PPC :

The highest efficiency in production is obtained by manufacturing the required quantity of product of required quality, at the required time by best and cheapest method. To certain this objective management employs PPC tool which coordinates all manufacturing activities. The main functions of PPC are the coordination of all the activities, which exist during production or manufacturing.

(I) Materials :

Raw material, standard finished parts, finished parts of products must be available while starting the operation within the time.

(II) Methods :

The purpose of this function is to analyze all methods of manufacture and select the best method according to the given set of circumstances and facilities. It determines the sequence of operations and the division of product into the assemblies and sub-assemblies, modified by the limitation of existing layout and work flow.

(III) Machines And Equipments :

Methods of manufacturing have to be related to the available production facilities coupled with a detail study of equipment replacement policy. Maintenance policy, procedure and schedules are also functions connected with managerial responsibilities for equipment. Design of economy of jigs and fixtures constitutes some of major duties of PPC.

(IV) Routing :

“The specification of the flow of sequence of operation and processes to be followed in producing a particular manufacturing a lot is routing”.

Routing determines that work will be done on the product of parts as well as where and How it will be done. It estimates the operations, their path, sequence proper class of machines and personnel required for these operations. An analysis of the article do determine what to make and what to purchase. Decision as whether to fabricate a component or purchase it from elsewhere. These are based on relative cost, technical consideration purchasing policies, availability of equipment, personnel, skill.

An analysis of article to determine what material are needed :- It depends upon the drawing, specifications, standard of quality, identification symbol, application in product. This depicts the additional material needed Figure 1.2 demonstrate the general procedure in production routing.

A determination of manufacturing operation and the sequence . This section establishes the operation necessary to manufacture the proper sequence on route sheet and operation sheet.

Determination of lot sheet. It depends primarily upon the manufacturing involved. If the product is to be manufactured strictly to a sold order, the customers order plus a certain average or allowance of stock, the lot size depends upon the primary of economic lot quantities etc., the quantity to manufacture so that for which the sum of the set-up and other preparation cost and the cost of carrying an inventory of the article manufactured at the minimum.

Determination of scrap factor : Is the anticipated normal scrap encountered in the course of manufacturing. The difference of amount of “SHRINKAGE’ depends upon the scrap factor encountered in the process best practice dictates the establishment of standard scrap factors for use in routing and scheduling.

Analysis of cost article : It includes cost accounting department for cost estimating of product.

Factors Affecting Routing Procedure:

1. Manufacturing type employed.
2. Availability of plant equipment and its component parts.
3. Characteristic of physical plant equipment and its component parts.
4. Human elements.

(V) Estimating :

When production orders and detailed operation sheet available with specification feeds, speed and use of auxiliary attachments and method, the operation time can be worked out. It may be consequently results in wide scatter of operation times and unduly large fluctuation and perhaps instabilities in time schedules.

(VI) Loading & Scheduling :

Machines have to be loaded according to their capabilities performance the given and according to the capacity. Machine loading is carried out in connection with routing to ensure smooth work flow work estimating, to ensure that the prescribed methods feeds and speed are best utilized. Careful analysis of process capacities so that flow rates along the various production lines can be suitable coordinated.

The distinction between planning and scheduling is largely semantically and based upon difference in detail and time period.

The schedule is very detailed plan for an immediate and relatively short time period. The difference between the plan and the schedule can be illustrated by looking at the objectives. The plan may ask to double production within two years. The schedule will to produce 300 units of articles during week number 1,200 units during week and so on.

Scheduling often refers to the specific determination of what is going to the production during the next few weeks or months. This involves determination of the individuals machines that are going to produce the items when they will be started and completed what quantities (lot or Batch sizes) they will be produced and with what materials. But many other activities are also scheduled such as maintenance, movement of goods and materials and oven staff meetings. In essence, a schedule is a detailed statement of how when and where specific resources are going to the employed to produce specified output or results.

At this levels of detail, the schedules is often in separable from the control system e.g. the financial areas, a budget can be regarded as a schedule of funds usage. On the hand, the budget is also an integral part of the control system for monitoring expenditure. The schedule thus provides a short range sequence of activities one for which we must have sensitive controls and rapid response time.

Scheduling can be very simple or very complex. Perhaps the most simple type schedule can be illustrated by an example drawn from cottage industry. A worker may be asked to produce as given number of work carvings or square meters of handloom fabric per week. The control is very simple and consists primarily of a count made each week, when the goods are lifted by employer.

Decision Rules :

The scheduling function is such a detailed process that it must usually be delegated to middle or lower management levels. Consequently, the schedulers, of themselves, are actually not in position to relate their activities to the overall company goals and objective. Yet their function is vital to the achievement of such ends. Consequently, it is necessary to establish decision rules which will help tie the two levels of management together.

Decision rules for scheduling should be fairly specific. Not only do they serve the purpose of linking the scheduling function with the attainment of total organizational goals but they provide consistency in scheduling practice so that people can be interchanged, so that schedules can be interpreted uniformly throughout the organization, and so that even one concerned will understand the process. They also make it possible to place much of the scheduling detail work on computers.

Decision rules can take many forms. The selection of the particular rules will largely depend upon the particular circumstance for which they are required. Competitive made of conditions, internal cost structures, the nature of the product, capacity consideration etc will all have their effect.

EXAMPLES OF POSSIBLE DECISION RULES INCLUDING THE FOLLOWING :

1. Schedule the longest jobs first.
2. Schedule jobs in the order they are received.
3. Schedule the job with the earliest delivery dates first.
4. Schedule jobs on a random basis.
5. Schedule first those jobs with the use production facilities for which we have the greatest idle capacity.
6. Schedule all jobs first which requires operation in department 1.
7. Schedule customer As order before all others.

Each of these rules (usually in combination with others) provides a means of regarding tasks. There are an almost unlimited number of possibilities (including the converse of some of the above and these are provided solely for illustration. It is worth noting that such decision rules are applicable to all scheduling processes not only these which deal with production operations.

Companies often experiment of determine the specific set of rules which make sense for their particular situations. In fact, it is possible to use part or projected at orders to simulate operations in the factory and determine the effect of a given set of decision rules in

advance of their actual introduction. This can be very useful and save considerable relief and confusion as follows the testing of such rules without the disruption of production.

Again, there is a caution involved in the use of decision rules. It is extremely difficult to design any set of rules which will cover every situation. Consequently, decision rules must be considered only as guidelines, not absolute, and flexibility must exist to deviate when necessary. On the other hand, it is probably sensible to require a thorough explanation every time a deviation is authorized, lest deviation from the rules become more common than applications of the guidelines. If the rules are well constructed they should tend to maximize benefits to the firm as a whole and should not be changed capriciously by individuals who cannot see the impact of such changes on overall corporate goals. However, this also implies the need for continuous review procedures to make sure that the rules are in tune with present conditions.

A point often overlooked is that if decision rules for scheduling are not formally and explicitly established, they usually evolve in through default. Each person involved in the scheduling process will usually have his own method-perhaps one that makes sense only to him, but still a method. Sometimes this may be the best alternative for a firm (e.g. the potential cost saving do not justify taking the time to establish a formal procedure). However, this should be explicitly determined. Otherwise, an organisation may be looking a major opportunity for improvement and enhanced efficiency.

(VII) Dispatching :

It is important mechanism of production control. Meaning of this term is sending to destination or starting something on way. When applied to production control, it means the assignment of work to different machines or work places which involves insurance of order and production form in order of their priority as determined by scheduling. In dispatching translated into reality or physical work which has been planned scheduling.

Duties of Dispatching :

1. Assignment of work to different machines of work place men.
2. Movement of material from stores to the first process and from process.
3. Issue of tool orders, instructing the tool department to collect and make ready jigs and fixtures, in advance of time, at which the operation will commence.
4. Issue of time ticket, drawing, instruction cards & other necessary information presented performing the work.
5. Issue of inspection order after each operation to determine the result in the number of pieces “good” and the “bad” and cause of spoilage.

6. Issue of more orders and collection of time tickets, drawings, instruction cards for all completed operations.
7. Recording time of beginning and completing jobs and calculate duration of, forwarding complete records to production department and time card pay roll department.
8. Recording and reporting idle time of machine and operation.

Dispatching Procedure :

Manner in which schedule or orders are issued depends upon whether the dispatching decentralized or centralized in the Decentralized : The manufacturing schedules or work orders in blanket fashion to the foreman or dispatch clerk within department. It is duty of foreman or clerk to dispatch the orders of material to each machine and operator.

In centralized dispatching : This involves the dispatching of orders from central dispatching division to machine or work station. Capacity and characteristic of each machine is recorded in central dispatching station. Regardless of type of dispatching it is customary for department to department themselves informed of the starting dates, progress of each order by means of wall chart visible index file or one of the several types of department dispatching boards.

Dispatching Rule:

Simple Rule :

1. Earliest due date : Run the job with the earliest due date, results in good date performance.
2. First come first served : Run the job which arrived in the waiting line first. Result at low variance of manufacturing cycle time.
3. Shortest processing time : Run the job which has the shortest set up plus machining for the current work centre.

Combination Rule :

1. Minimum stock : Slack equals calendar time remaining minus processing time remaining or slack equals date minus present time minus set up and machining time all remaining operation.
2. Critical ratio : The critical ratio are made to order work is a slack type rule. Critical equals 0 to due date minus present time divided by number of days required to complete the job order.

(VIII) Expediting :

Follow up which regulates the progress of materials and parts through the production process. This closely inter elated with activities of dispatcher to whom is delegated scheduling responsibility.

Follow up is that novel tool which acts as a regulator of material and components parts when they are traveling on the path of performance as laid down by sheets and schedule charts. It serves as a catalytic agent to fuse the various separate an unrelated production activities into the unified whole that means progress.

TYPE :

1. *Materials* : To follow up purchased materials is responsibility or purchasing department. This can be accomplished most simply by filling one copy of requisition in a daily follow up file or in ticket file according to the date of materials is due to be received.
2. *Work in progress* : This follow up the work by checking the process and recording the production accomplished by production line for comparison purpose with preplanned schedules. It is the duty of follow-up men or expeditors to advise the foreman as to the best sequence in which the orders can be run so as the required part in which order to be fabricated and brought it together at right time, place for the completion of finished product.
3. *Assembly and Erection* : Responsibility for assembly and erection of products in assembly manufacturing is almost invariably rested. When all the parts of an available, the follow up man permits assembly of election of products in start in case of large complicated product this is very necessary.

(IX) Inspection :

Another major control is inspection. Its finding land criticism are of the importance both in execution of current program and both in planning stage of fibre undertaking when the limitations of the processor, method and manpower are known. These limitations can form a basis for future investigations in evaluating the showed improving production methods.

(X) Evaluating :

Perhaps the most neglected, but on an essential link between control and forwarding is that of evaluating. The essential task of dispatching and evaluating are concerned with the immediate issue of production and with measures that will be as certain fulfillment target. Valuable information is gathered limited in nature and unless provision is made so that all the accumulated information can be properly digested and analyzed data may be irretrievable lost. Thus here the evaluating function comes in to provide a feedback mechanism on the longer term basis so that the past experience can be evaluated with the view to improving utilization of method and facilities. This is the integral part of control function.

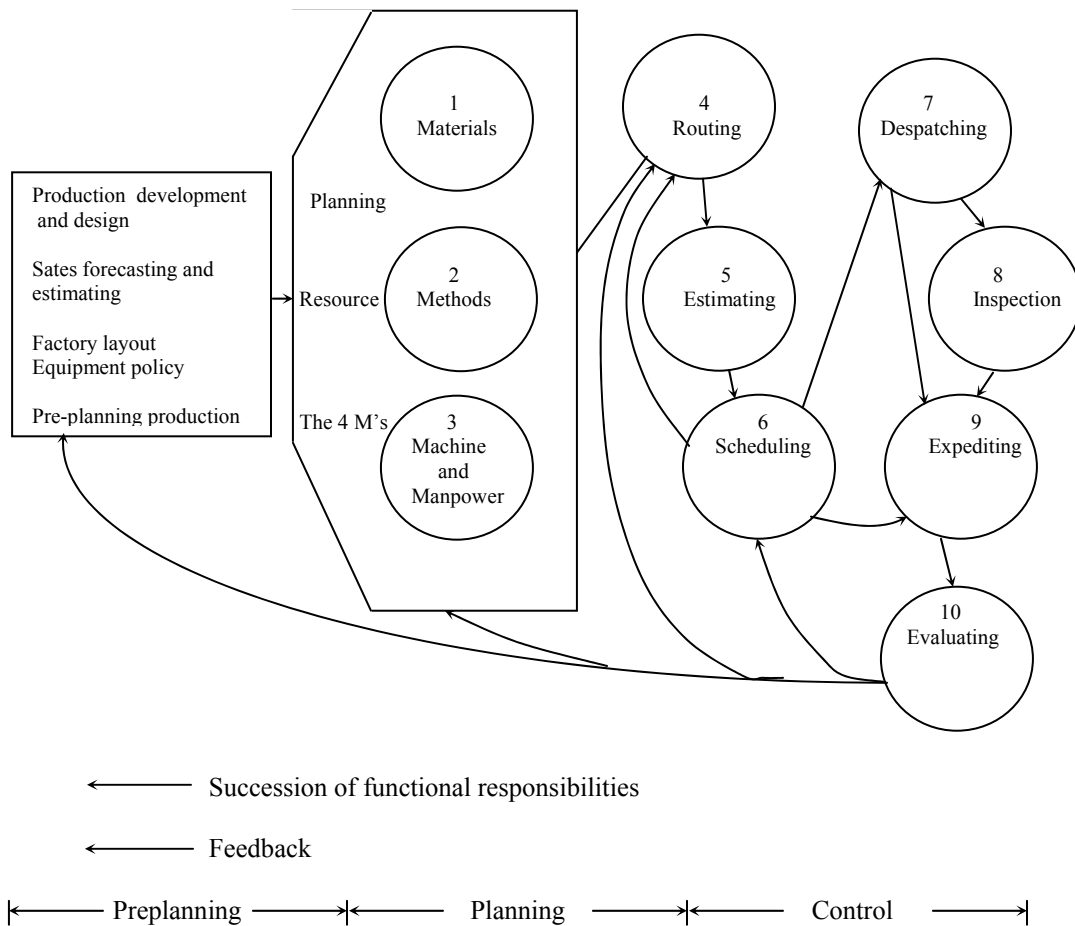


Fig. 1.1 The ten function of production planning and control cycle.

MATERIAL PLANNING

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

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

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

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

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

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

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

1. Bill of material quantity, quality & specification of material
2. Production of Assembly schedule.
3. Supply lead times & dependability.
4. Manufacturing capacity.
5. Overall economy.

1.16 MATERIAL PLANNING FUNCTIONS AND OBJECTIVE.

1. Translation of the sales projections into long term requirements.
2. On the basis of updated production plan adjusted to the latest sales demand to adjust the materials accordingly.
3. To project the facilities required for the materials management.
4. Setting up of consumption standards, for working out requirements.
5. To perform value analysis to determine the intrinsic worth of materials.

6. To decide whether to Make or Buy.
7. To highlight exception & priorities.
8. To keep inventories as low as possible.
9. To procure parts as & when needed by the production/assembly schedule.

1.17 TYPES OF INVENTORIES

The term inventory refers to the stock of some kind of physical commodity like raw materials, component parts, supplies & consumable stores, work-in-progress & finished goods. The analysis of the cost structure of many of the product reveals that inventories cost range from 40% to 85% of the product cost. Thus inventories indicate a major application of financial resources & efficient inventory control can contribute substantially to the profitability of the business.

The type and amount of inventory which an organisation should hold will depend upon several aspects including the product manufactured, or service provided/service range type of manufacture and span of process.

The Principal Types of Inventories Are :

INPUT	—————→	Production Inventory
PROCESS	—————→	In-process Inventory
OUTPUT	—————→	Finished Inventory

1. **Production Inventories** : Items which go into the final products raw materials and bought out components.
2. Maintenance, Repair and Operating Inventories : Items which do not form a part of final product but are consumed in a prod. Processes, spare parts, Consumable items etc.
3. **In Process Inventories** : Work-in-progress items which are partly manufactured and await the next stage in process.
4. Finished Goods Inventories completed products ready for dispatch.
5. **Miscellaneous Inventories** : Which arise out of the above four types of inventory scrap, surplus and obsolete items which are not to be disposed off.

Inventories are also classified as :

1. **Transit Inventory/Pipe line inventory** : This inventory results because of the transportation time required. Transit inventory exist between factory & place of supply or between & factory.
e.g. Coal, iron ores etc.

2. *Buffer inventory/Safety Stock Inventory/Fluctuation Inventory* : These are the inventories maintained to adjust with variation in demand & supply & to avoid out of stock condition & back ordering.

3. *Anticipation Inventory* : These inventories are maintained to adjust with sudden change in demand (e.g. seasonal products). Instead of producing more in particular season a producing less during rest of the year, inventories can be allowed to build up before the season. This will avoid idle or shut downs & resource utilization can be increased.

4. *Decoupling Inventories* : Same as in process inventories to ensure smooth & uniform work flow.

5. *Cycle Inventories/Lot size Inventories* : These are maintained wherever the user makes or purchases material in larger lots than are needed for his immediate purpose to take the advantages of quantity discounts, to keep shipping cost in balance, & to hold down clerical costs & handling cost. So these inventories are maintained purely due to the interest of management.

1.18 ABC ANALYSIS OR VALUE DISTRIBUTION

ABC Analysis is the basic method of stock control generally used in a medium size company. Inventory in a to execute proper control it is necessary to take selective approach & find out the attention required for each type of item, according to its importance.

In relation to the inventory control the curve demonstrates the 'law' that a small proportion of the stocked item accounts for a large proportion of inventory cost or value. Their relationship is often referred to as 80/20 'law' i.e., up to 80% of firm's total inventory cost or value is accounted by about 20 % types of encourage categories various types of inventory items in to three classes viz. A, B & C.

Class 'A' : Those relatively few types of items (upto 20%)

Age of total cost (upto 80%)

Class 'B' : Slightly larger no of types of items (upto 30%) which account percentage of total cost (upto 15%)

Class 'C' : That large no. of types of items which account for a very small (up to 5%) of total cost.

In this analysis, priority is determined by the money value of the importance of the item. Hence class 'A' items need to be very closely controlled by the management analysis can be referred as the basic analytical material management tool.

1.19 EXAMPLE OF A CLOTHING

WHOLE SELLER, FOR ABC ANALYSIS

The table below shows the bought in prices & annual sales of the set of different types of garments which are held in stock by a whole seller. Construct an ABC chart for these items & suggest which items should be treated as class A, B, & C.

Item Type (Items/Yr)	Purchase price (Rs.)	Annual sales
A	8	1250
B	18	450
C	30	75
D	25	10
E	3	280
F	4	080
G	18	45
H	7	250
I	12	150
J	26	30

Solution :

Calculation of Annual Value (Step I)

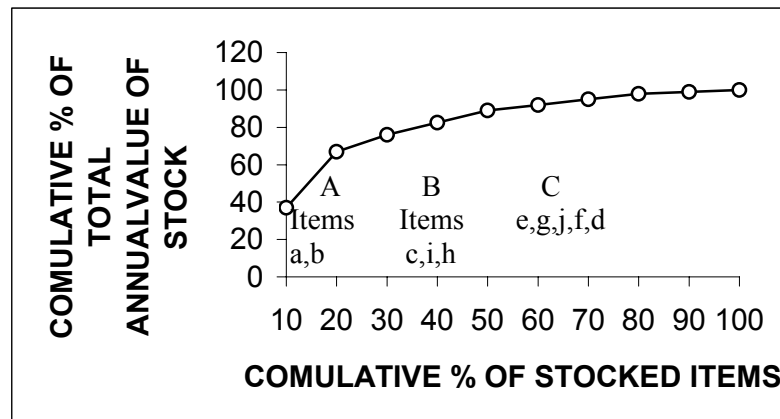
Items	A	B	C	D	E	F	G	H	I	J	10
Annual Values or uses	10000	8100	2250	250	340	320	810	1750	1800	780	26900

Where, 10 – the column is total annual value.

Order items by descending annual values & calculate common annual value (Step II)

ITEM TYPE	ANNUAL VALUE	CUMULATIVE % (OF 26000)	CLASS
A	10,000	37	A
B	8,100	67	A
C	2,250	76	B
I	1,800	82.5	B
H	1750	89	B
E	840	92	C

G	810	95	C
J	780	98	C
F	320	99	C
D	250	100	C



SUMMARY (STEP IV)

CLASS	ITEMS	% ITEMS	ANNUAL VALUE OF CLASS	% OF ANNUAL VALUE
A	a,b,	20	18,100	@ 67
B	e,i,b	30	5,800	@ 20.5
C	e,g,j,f,d	50	3,000	@ 12.5

CONCLUSION :

It is evident from the discussion that to have an healthy organization the pre planning and post-planning activities are to be ground property at the initial stage turning organization, after preplanning the links are connected with PPC department planning, evaluation, adjustment, feedback and overall control. Ten functions of PPC as if ten Commandments to be followed in any manufacturing industry. Depending upon the nature of production and size of unit, these functions are glooming in determination position and when required. But it appears in one of other forms. We cannot, therefore abolish its

existence in the organization. In case, it has been evacuated purposely it fleets badly on the associated activities and ten departments involved thereon. This has been depicted precisely in the data sheet.

We observed that in almost all functions, PPC is the governing department and therefore it has been after every function, if not in existence. Therefore, PPC can be considered and value as a heart on the manufacturing of any type and any size.

Therefore to have an healthy organization, less confusion in workers, proper feeding to top management to chalk out their dynamic policies, PPC department plays a very important and vital role in organization. Naturally, it should be made more dynamic, powerful by shoulding more authorities and responsibilities on the experienced and conservative staff of PPC department.

Gov1990

P.No.1 :- What are the main benefits of PPC ?

P.No.2.- "Communication is very imp function of business office; Issue the statement highlighting the characteristics of good of inter communication.

N/1010

What is the need of the PPC? Explain production control as a nervous system?

(3+4)

"Scheduling" planning function and "Expedities" a set of function. In a small firm it was proposed to allocate been representative "arm perion should you approve of suit

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2. SALES FORECASTING

A forecast is an estimate of the level demand to be expected for a production of several products for some period of time in the future.

Forecast is made of sales (in Rs.) or physical units under a proposed marketing or program & under an assumed set of economic & other force outside the unit system).

Forecast should cover a time period at least as long as the period of time required to make the decision & to put that decision into effect.

Applications/uses/purposes :

There are 3 major purposes.

- 1) To determine necessity for & the size of plant expansion (Facility Forecast)
- 2) To determine intermediate planning for existing products to be manufactured with existing facilities.
- 3) To determine Short-time scheduling of existing products to be manufactured on existing equipments (Product Forecast)

Methods of Sales Forecasting/Types

Forecasting for new product

1. Direct Survey method.
2. Indirect Survey method.
3. Comparing with established product.
4. Limited market trial.

Forecasting for established product

1. Related information method.
2. Market Research.
3. Sales force composite method
or Subjective opinion method.
4. Jury of Executive opinion.
5. Projection method.
6. Statistical method.

Forecasting for a new product is difficult task as no past information is available to predict the future.

1) Direct Survey method : In this method, representative sample of customers are approached & asked, what they intend to buy. By doing so, it is possible to predict, with some degree of certainty how the population will respond. Here economic, political, changes, customs, habits, social requirements are considered.

2) Indirect Survey method : In this method the attitude & behaviour of the customers is predicted through salesman. Agents, whole sellers, retailers etc.

3) Comparing with Established Product :- At times the product under consideration is comparable to an existing product. So sales figures can be compared.

4) Limited Market Trial : Some times limited selling technique is adopted to product acceptance of the product.

Forecasting for Established product is explained below.

1) Related information method : (Forecast based on an index) in this method which directly varies with the sales volume is found (e.g. birth date is related information for the forecast of the sales of baby food & forecast is made).

2) Market Research : Through critical analysis of the marketing forces, changing pattern of socio-economics pressures, political changes in style, attitudes, fashion etc, we can diet the future demands of the product.

3) Sales force composite method : (Subjective opinion) in this forecast, all the marketing & sales peoples (Sales-man, traders middle men etc) express their considered opinion of the volume of the sales expected in the future. These opinions are then collected & evaluated.

4) Jury of Executive Opinion Method : Here opinions of experts are invited about the sale in future. It is simple & fast but not scientific.

5) Projection Method : Based on the historical data, future can be projected to some extension.

A line drawn through known information is projected into the forecast area to predict what the sales volume will be for future periods. Projection of future can be done either by time series Analysis or Correlation, regression Analysis tech.

Time series Analysis : A time series is a chronological data which has some quantity such sales rupees, sales volume, prod. figures, imports, exports, number of passengers traveling by Air lines etc. as dependent variable & unit of time as independent variable.

The movements or variations of the dependent variable may be

Long period changes (Trend)

Short period changes (Seasonal, cyclic, irregular)

Long period tendency of the data to increase or decrease is called secular or basic trend. A secular or long term trend refers to the smooth & regular movement of a series reflecting continuous growth, stagnation or decline over a rather long period of time.. We are chiefly concerned with the general tendency of data. As long as we notice an upward or down word trend movement in the data over the whole period, we coriclude secular trend.

e.g. There is secular rise in agriculture production in India. Because of since last 25 year it has been found that except for a year or two, the production is increasing. Basic secular trend (long term) may be linear or non-linear.

The important method of making inference about the future on the basis of what happened in the past is the analysis of time series. After analysing the time series plant production, finance, personnel, marketing etc. can be made to meet the variation in the demand.

Time series is a multiplicative model of 4 – components.

$$O = T \times S \times C \times I$$

T - Basic Trend, S – Seasonal fluctuations

C - Cyclic fluctuations, I – irregular, Erratic, random, fluctuations.

METHODS OF ESTIMATING TRENDS :

1. Methods of Inspection or freehand methods – Once the given time series data have been plotted on a graph paper, a line is drawn through the points which in statisticians opinion best describes the avg. long term growth.

2. Methods of Averages :

a) Selected point method : Here the values are selected of the years which are considered to be the most representative or normal. Then a straight line is drawn.

b) Semi-avg.method : Here data is divided into two equal halves & averages for each half is calculated. The avg. for half is taken to be representative of the value corresponding to the mid-point of the time interval of that half. Thus these two points determine the position of a trend line. The trend line can be extended to estimate future values or intermediate values.

c) Moving Avg. methods : It is discussed later on.

3) Statistical methods : It is statistical analysis of past demand. It is most accurate method provided there is relationship between past & future. In fact past offers best basis for decision on future action. However one must modify the prediction form past data if he

knows that certain events will or will probably happen in future e.g. events like expansion of sales area, advertising, withdrawal of competitor etc, will tend to increase the sale. On the other hand events like entry of new competition, product becoming calculated will tend to develop sale. Such considerations should be reflected in new forecast.

In statistical method we are going to consider following 3 cases.

1. Level demand with Random variation.
2. An Upward Trend with Random Variation.
3. Cyclic (Seasonal) Demand.

General Approach To Statistical Forecasting :

If we assume that use of statistical methods applied to past data is a realistic of forecasting future demands, we should then proceed as follows.

1. Make a plot of demand versus time. (Demand as ordinate & time as abscissa).
2. Determine which statistical technique to try.
3. Evaluate the expected error.
4. Make a decision to use the technique under consideration or attempt to find a being one.

Above approach is demonstrated by solving three examples below.

Example 1. Level Demand With Random Variation.

In this case demand remains essentially constant but super imposed random variation. The use of constant forecaster is generally adequate & appropriate.

Demand data for 12 months is given as –

Months	J	F	M	A	M	J	J	A	S	O	N	D	Total
Demand (d)	90	111	99	89	87	84	104	102	95	114	103	113	1191

Let up plot a graph between time and demand.

From the graph it is clear that it is level demand with random variation about constant value of demand.

Constant forecaster is given by –

$$\text{Arithmetic avg. } \bar{d} = \frac{\text{Total demand}}{\text{No. of period}} = \frac{1191}{12} = 99.25 \text{ units*}$$

99 Units can be used as a forecasting function. That is we would forecast that demand will be 99 units for each of the next several months.

We want to evaluate this method (arithmetic avg.) forecasting . This can be done by determining the standard error of estimation or standard deviation.

$$s = \sqrt{\frac{\sum (d - \bar{d})^2}{n-1}} = \sqrt{\frac{1180}{11}} = 10.4 \text{ units}$$

d - Actual demand

n - No of periods included

\bar{d} - Avg. demand

The calculation are shown in tabular form.

Month	\bar{d}	Demand (d)	$d - \bar{d}$	$(d - \bar{d})^2$
J	99	90	9	81
F	99	111	12	144
M	99	99	0	0
A	99	89	10	100
M	99	87	12	144
J	99	84	15	225
J	99	104	5	25
J	99	102	3	9
A	99	95	4	16
S		95	4	16
O		114	15	225
N		103	4	16
D		113	14	196
		1191		$\sum (d - \bar{d})^2 = 1180.25$

Now we can say that we are 95% confident that the demand in any month will lie between 79 and 119 units. 95% confident means, in 95 month out of next 100 months demand will lie between 79 and 119.

$$\begin{aligned} 95 \% \text{ confidence limits} &= \text{avg. demand} \pm 1.96 \% \text{ deviation} \\ &= 99 \pm (1.96 \times 10.4) \\ &= 79 \ \& \ 119 \text{ units.} \end{aligned}$$

Note : 99.7 % confidence limit = Avg. demand \pm 3 std. deviation.

And 68 % confidence limit = Avg. demand \pm std. deviation.

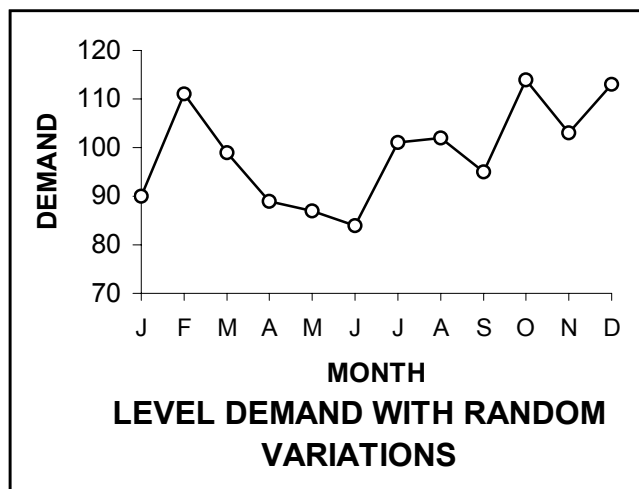
Assumptions made:-

1. Demand data studied for the periods are truly representative of the demand.
2. The cause system was unchanged & unchanging during the period studied.
3. Same cause system will continue to be operative for some time into the future.

Summary :-

Results of our analysis are –

1. Forecast is that the demand will be 99 units per month.
2. The std. deviation of demand is 10 units.
3. In 95 of 100 months we would expect demand to fall between 79 & 119 units.
(at 95 % confidence level)



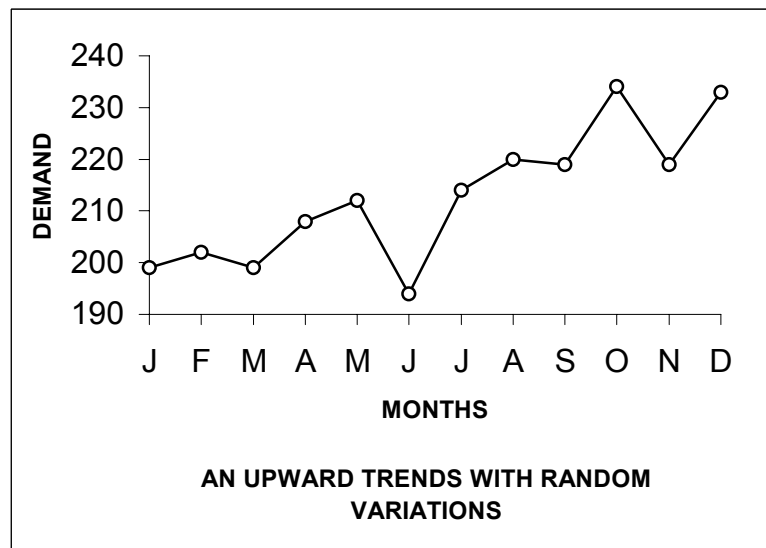
Example 2:- An upward trend with random variations :

Data given & the calculations done are shown below.

Months	Demand (d)	t	D ¹ -19343	(d – d) ²
J	199	1	196	9
F	202	2	199	9
M	199	3	202	9
A	208	4	205	9
M	212	5	208	16
J	194	6	211	289
J	214	7	214	0

A	220	8	217	9
S	219	9	220	1
O	234	10	223	121
N	219	11	226	49
D	233	12	230	9
$\Sigma d = 2553$		$\Sigma t = 78$	$\Sigma(d-d)^2 = 530$	Σd

Plot the graph demand and time



Where,

d^1 – Predicted / estimated value of demand

$$b = \frac{6 [2 \sum dt - (a+1) \sum d]}{n (n^2 - 1)} \quad t = \text{time (independent variable)}$$

$$a = \bar{d} - b \bar{t}, \bar{d} - \text{Avg. demand}, \bar{t} - \text{Avg. time}$$

$$\therefore \bar{d} = \frac{2553}{12} = 212.75$$

$$b = \frac{6 [2 \times 17030 - 13 \times 2553]}{12 (144 - 1)}$$

$$= 3.05$$

$$a = \bar{d} - b \bar{t}$$

$$= 212.75 - 3.05 (78 / 12)$$

$$= 192.92 \approx 193$$

Substituting values in eqn (1)

$$D^1 = 193.00 + 3t \text{ -----eqn (2)}$$

Assuming that, liner forecaster is acceptable, we get forecasts for next years by substitute value of 't' between 13 & 24 in eqn (2)

These forecasts are tabulated below.

Forecast by a liner forecaster.

Months	J	F	M	A	M	J	J	A	S	O	N	D
Period t	13	14	15	16	17	18	19	20	21	22	23	24
Demand d ¹	233	236	239	242	245	248	251	254	257	260	263	266

Estimate of Error :- it is given by

$$S = \sqrt{\frac{\sum (d_1 - d_1^1)^2}{n-2}}$$

F = 2 is a degree of freedom as their are two yrs.

Here, we require to find values of dl for that, substitute all value of time (1 to 12) in

Eqn – (2) i.e. $d^1 = 193 + 3t$

$$\therefore S = \sqrt{\frac{560}{12.2}} = 7.3$$

We can expect that the future demand will full between $d^1 + 14$ & d^1-11 which confidence.

95 % confidence level = 1.96 × std. dev.

$$= 1.96 \times 7.3$$

$$= 14$$

Summary :-

- 1) The forecast demand will follow the regression line $d^1 = 193t + 3t$.
- 2) The Std. error of our estimate is 7.3
- 3) In 95 of 100 months we expect the demand to be between $d^1 + 14$ & $d^1 - 14$ units. Again correctness of our forecast is a function of stability of the cause system.

Example 3 : Cyclic (Seasonal) Demand :-

Date given & calculations done are shown below.

Month	Demand(d)	T	Sin 10/6 t	Cos(10/6)t	d ¹	(d-d ¹) ²
J	72	1	0.500	0.866	82	100
F	83	2	0.800	0.500	87	16
M	92	3	1.000	0.000	95	9
A	107	4	0.866	-0.500	103	16

M	114	5	0.5000	-0.866	110	16
J	129	6	0.000	-1.000	114	225
J	91	7	-0.500	-0.866	114	529
A	108	8	-0.866	-0.500	109	1
S	116	9	-0.1000	-0.000	101	225
O	79	10	-0.866	0.500	93	196
N	92	11	-0.500	0.866	86	36
D	93	12	0.000	1.000	82	121
	$\Sigma d - 1176$				$\Sigma d^1 = 1176$	$\Sigma (d-d)^2 = 1490$

Cyclic forecaster is given by –

$$d^1 = \bar{d} + u \cos \frac{2kt}{n} + v \sin \frac{2kt}{n} \quad \text{-----(1)}$$

d^1 = demand in future

$$a = \bar{d}$$

values of 'u' & 'v' can be found from the determinant –

$$\begin{vmatrix} d^1 & 1 & \frac{\cos 2\pi t}{n} & \frac{\sin 2\pi t}{n} \\ \Sigma d & N & 0 & 0 \\ \Sigma d \cos \frac{2\pi t}{n} & 0 & n/2 & 0 \\ \Sigma d \sin \frac{2\pi t}{n} & 0 & 0 & n/2 \end{vmatrix} = 0$$

Subst. Values in determinant :-

$$\begin{vmatrix} d^1 & 1 & \cos \frac{2\pi t}{n} & \sin \frac{2\pi t}{n} \\ 1176 & 12 & 0 & 0 \\ -98 & 0 & 6 & 0 \\ -19.8 & 0 & 0 & 6 \end{vmatrix} = 0$$

Divide 1176 by 12 to get value of 'a'

Divide -98 by 6 to get value of 'u'

Divide -19.8 by 6 to value of 'v'

∴ We get

$$a = 98$$

$u = -16.3$

$v = -3.3$

$\therefore d^1 = 98 - 16.3 \cos \frac{\pi t}{6} - 3.3 \sin \frac{\pi t}{6}$ ------(3)

Forecast by Cyclic forecaster can be obtained by putting $t = 1$ to 12 in eqn (3).

These values are shown below.

Month	J	F	M	A	M	J	J	A	S	O	N	D
Expected demanded	82	87	95	103	110	114	114	109	101	93	86	82

Std. error of estimation is $S = \sqrt{\frac{\sum (d_1 - d_1^t)^2}{n}}$

$S = 12.7$

Forecast at 95 % confidence level $d^1 \pm 1.96 \times 12.7$
 $d^1 \pm 25$ units

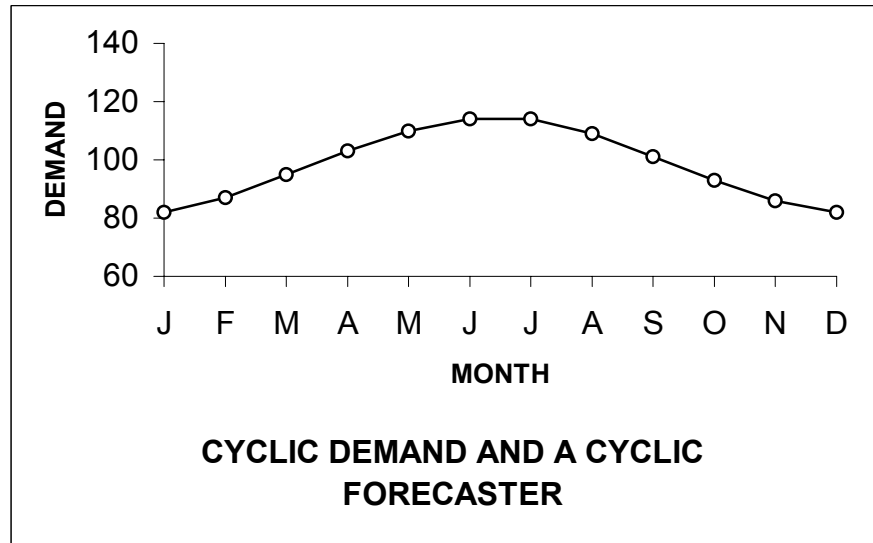
Summery :-

1) Expected demand will be

$d^1 = 98 - 16.3 \cos \frac{\pi t}{6} - 3.3 \sin \frac{\pi t}{6}$

2) Std. error of est. of the demand is 12.7

3) 95 of 100 months, we would expect demand to be within ± 25 units



NOTE :-

When the demand data is given but the type of forecast (i.e. constant, linear or cyclic) is not given, then in order to decide which forecaster is to be used (i.e. constant, linear or cyclic), following method should be adopted.

- Plot the graph between the given demand figures & the time months)
- Observe the nature of graph.
- Decide whether the demand pattern is constant, linearly increasing or cyclic.
- Select & use the forecaster accordingly.
- Otherwise all three forecasting functions (const, linear & cyclic)

Should be applied to the given data initially & the forecasting functions yielding minimum standard error of estimation should be selected & used in future.

Other methods of forecasting :-**1) Moving Avg. Forecaster :-**

A moving avg. can be used as forecaster.(other than deciding the trend) The forecast is obtained by summing the data pts over a desired no of past period.

Extending the moving avg. to include more periods increases the smoothing but decreases the sensitivity of forecast to more recent data. Each period, it new moving avg. is computed by dropping the demand for the most prior period & adding the demand for the most recent period.

In some cases, the moving avg. method is advantageous, where as in others it not give rather inaccurate results Moving avg. is performed to eliminate periodic fluctuating time series.

Period of moving avg – period of fluctuations (length of cyclic movements in data)

Generally 3 – yearly, 5 – yearly, 7 & 9 yearly periods are taken to compute moving average.

Ex. The following series relates to the production of a commercial concern of 8 yrs.

Year	1974	75	76	77	78	79	80	81
Prodn	15420	14470	15520	21020	26120	31950	35360	356
Units								

Find the trend of prod". Assume a 3 – year cycle and ignore decimals.

Solutions :- Calculations of trend of prod" by the method of moving average.

Year (1)	Prod'' (2)	3 – yrly moving Total (3)	3 yrly moving avg (4)
1974	15420	-	-
75	14470	45410	15136
76	15520	51010	17003
77	21020	62660	20886
78	26120	79090	266363
79	31950	93440	31146
80	35370	102990	34800
81	35670		

Advantages :-

- 1) It gives a fair good picture of general long term movement in data provided data contains uniform cyclic & if the trend in data is linear of approximate.
- 2) No personal prejudice & bias of the computer.
- 3) Cyclic fluctuations are completely eliminated if the period of moving avg is equilibrium to the period of cycles.
- 4) Simpler without fitting the curve.

Disadvantages :-

- 1) Tendency to cut out corners which results in loss of data at the ends.
e.g. 2 yrly cut 1 value 7 yearly – 6 values
3 yrly cut 2 values
5 yrly cut 3 values
- 2) No mathematical eqn. For forecasting.
- 3) Sharp turns in graph reduces to small curvatures.
- 4) Care is to be taken for data selection & period of moving avg.
- 5) Trend will accurate only if cyclic & irregular fluctuations are uniform both in duration & amplitude.
- 6) Tends to lag behind the trend.(means it gives lower values than regression line for an upward trend & vice-versa)

2. Exponential Smoothing Method:-

When a new observation is made after old forecast is completed (based on any method), then certainly there will be difference between old forecast & new observation.

Therefore forecast can be revaluated for next observation, from old observation allowing an error. The correctness will be achieved by fraction of the error.

$$\therefore \text{New Forecast} = \text{old Forecast} + \alpha (\text{Latest observation} - \text{old Forecast})$$

Where, α = Smoothing Factor
= 0 to 1

Validity must be determined by an appropriate

Moving Rang Chart:- (For verification & Control of forecast)

It is designed to compare the observed values & predicted values of some demand the moving range is defined by

$$MR = (d_1^1 - d_1) - (d_{1-1}^1 - d_{1-1})$$

Avg. moving range is detmed by

$$\overline{MR} = \frac{\sum \epsilon MR}{(n-1)}$$

The central line for M.R. chart is at 0

The control limits are

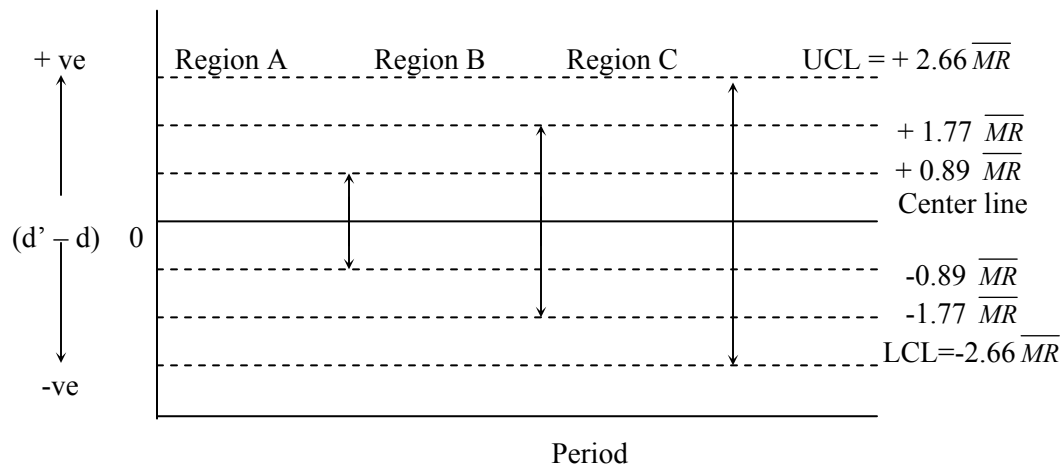
$$UCL = + 2.66 \overline{MR} \text{ (Upper control limit)}$$

$$LCL = - 2.66 \overline{MR} \text{ (Lower control limit)}$$

The variable to be plotted on the M.R. Chart is –

$$dt = d_1^1 - d_1 \quad \Delta d_1 = (d_1^1 - d_1)$$

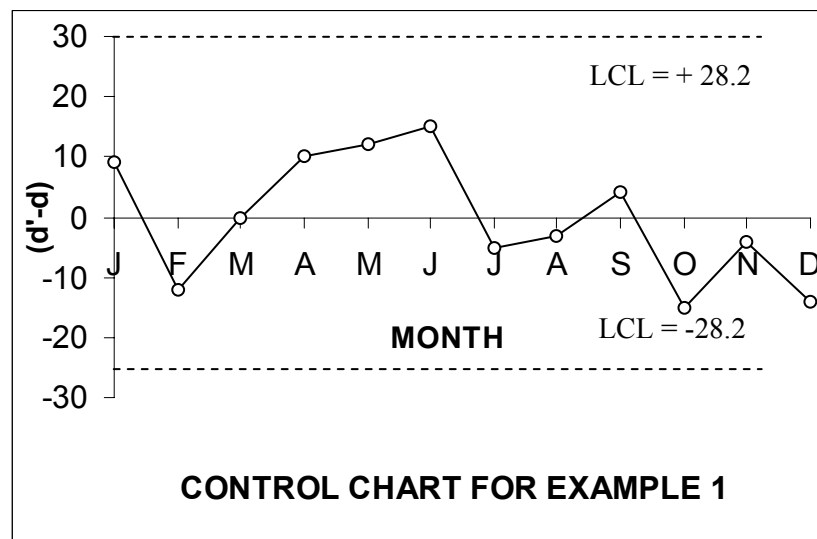
Control Chart :-



Verifying the const. forecasting of example 1 :**Calculation for the M. R. Chart to verify the control given for forecasting.**

Month	Period 't'	Forecast d'	Demand (d)	(d ¹ -d)	MR
J	1	99	90	0	
F	2	99	111	-12	21
M	3	99	99	0	12
A	4	99	89	10	10
M	5	99	87	12	2
J	6	99	84	15	3
J	7	99	104	-5	20
A	8	99	102	-5	2
S	9	99	95	4	7
O	10	99	114	-15	19
N	11	99	103	-4	11
D	12	99	113	-11	10
					$\Sigma MR = 117$

n example No.1 We established $d^1 = 99$ units as a forecaster. We shall new test its validity.



$$\begin{aligned} \therefore \overline{MR} &= \frac{\sum MR}{n-1} \\ &= \frac{117}{12-1} = 10.6 \end{aligned}$$

$$UCL = +2.66\overline{MR} = 2.66 \times 10.6 = +28.2$$

$$LCL = -2.66\overline{MR} = -2.66 \times 10.6 = -28.2$$

- 1) Of three successive pts, are two or more in either region A.?
- 2) Of five successive pts, are four or more in either region B.?
- 3) Are the eight successive pts, on either side of center line ?

All conditions are satisfied therefore the control chart indicates a stable cause system & establishes the validity of $d^1 - 99$ as a forecaster for ex.1

Controlling the forecast of Ex. L by Moving Range Chart :-

Controlling :- While controlling, when out – Of condition is observed, action relative to the forecaster or the demand should be taken.

Actions regarding forecaster are –

- 1) Revise it including new cause system.
- 2) Wait for further evidence.

But action of data or forecaster should be taken only after a consideration of all aspects of the cause system. An analysis of data alone would generally be insufficient.

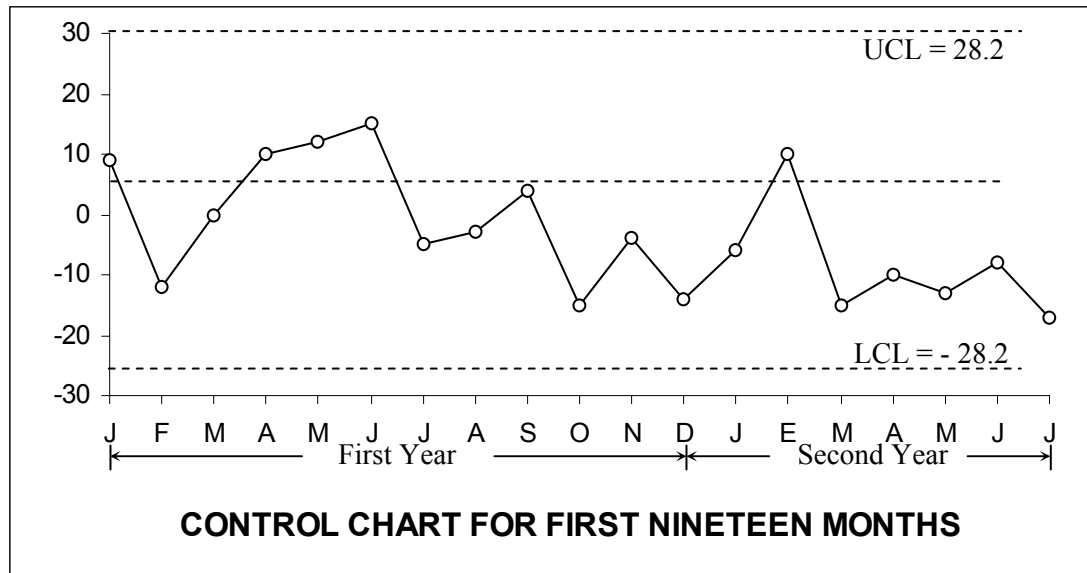
Actions regarding demand & its cause system are –

- 1) Changes in advertising
- 2) Changes in sales force
- 3) Changes in price etc.

In Ex. 1 Our forecast was 99 units. We have already checked its validity on M.R. chart for absolute mini data. But the actual demand (sale figure) for seven month of next (second) year as under –

Month	Period (t)	Demand (d)	($d^1 - d$)
J	13	105	-6
E	14	89	+10
M	15	114	-15
A	16	109	-10
M	17	112	-13
J	18	107	-8
J	19	116	-17

Let us plot this data also on the



CONTROL CHART OF FIRST NINETEEN MONTHS

Again the rest for out of control condition should be applied. By doing so we find out the point for period 19 indicates out of control conditions. Therefore new forecast the basis of 19 period should be established. Also new values of MR, UCL, LCL should be calculated.

$$\therefore \text{Avg. forecaster } \bar{d} = \frac{19.13}{19} = 10.2$$

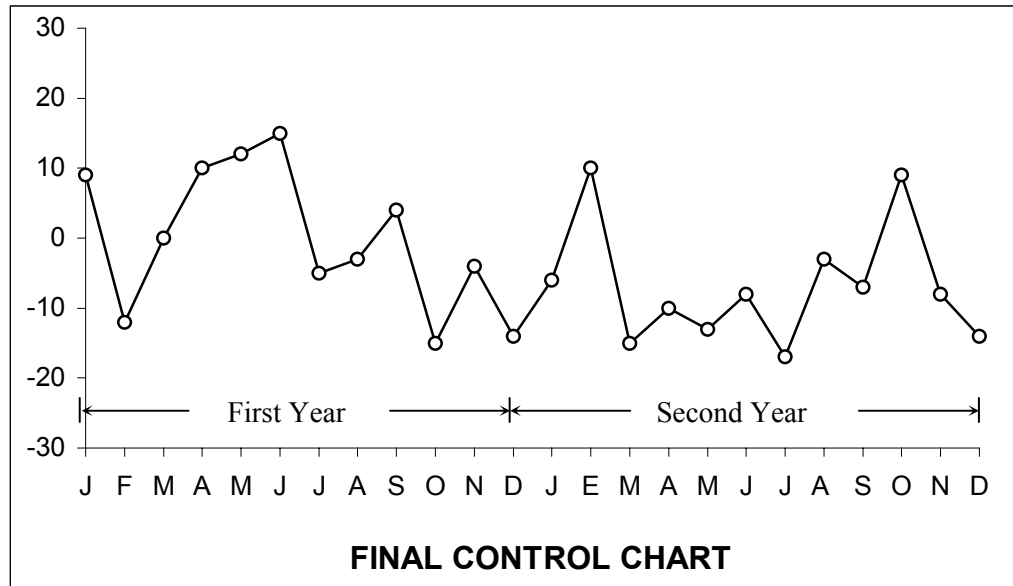
$$\& \overline{MR} = 10.4$$

$$UCL = 27.8 \quad 1.77 \overline{MR} = 18.4$$

$$LCL = -27.8 \quad 0.89 \overline{MR} = 9.25$$

$$S = 10.4$$

Again prepare the fresh control chart for above values as shown below. From the control chart we shall conclude that $d^1 = 102$ is better forecaster than $d^1 = 99$. We shall use new forecaster in future until we will find evidence for out of control condition in the control chart. So it is a continuous process.



Points for period nos 20, 21, 22, 23 & 24 are placed in the above chart using the following given data.

Months	Period (1)	Demand (d)	
A	20	105	
S	21	109	-7
O	22	93	9
N	23	110	-8
D	24	116	-14

Same procedure can be adopted to verify & control the linear forecaster & cyclic forecaster of Ex 2 & Ex 3 respectively.

Q.No.1. Explain various types of forecasts.

Q.No.2 . Define production forecasting.

Q.No.3. Merits & demerits of 'moving Avg. forecasting.

Q.No.4. third moving range charts are helping in verification of forecasting.

Q.No.5. Discuss the imp of sales forecasting for production scheduling.

Q.No.6. What do you mean by Experimental smoothing forecasting.

Q.No.7. Why it is necessary to revise the forecasts? How do you want of central conditions using is moving range chart.

Q.No.8. Explain the forecasts based upon the averages.

Q.No.9. What is the std. error of estimate.

Q.No.10. Discuss the merits of Demerits of 'Moving Avg forecasting.

- Q.No.11. For the forecasting of seasonal demand which method of forecasting you will suggest and why?
- Q.No.12. Problem on Regression lin [ICM – O.P.]
- Q.No.13. What is the use of indicators and correlation analysis.
- Q.No.14. Application of production forecasting?
- Q.No.15. Which are the factors influencing on forecast?
- Q.No.16. Define ‘Avg. Moving Range’. How UCL of LCL are demerits decided in MR chart?
- Q.17. What do you mean by forecasting? Brief out the diff. forecasting techniques for established product and new product.

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3. PRODUCTION PLANNING

3.1 THE PURPOSE OF DATA SHEETS

It is obvious that the elimination of waste or overloading of any of the resource industry, including materials, machines, methods and money as well as manpower depending on appropriate planning of the use of available resources and their efficient control during production phase, selling and their after related activated. Planning and control are essential activities to the rapid expansion of industry and employment.

Control requires a particular pattern of activities to operate properly in a dynamic and imperfect world. It is difficult to improve because the behaviour of pattern of events difficult to understand and also because control have the emotional overtones associated with love of power and fear of being dominated. Therefore, it is essential to have a transferable for objectives analysis, as otherwise subjective emotions will present clear thinking on the desirable use of Techniques. It is for this reason that specific Data sheets are reputed to introduce a diagrammatic rotation for recording and studying planning and control inspection to shows that without such a representation any decision and discussion of control is obsortive.

The Data Sheets thus aims at establishing a framework for the study and important of planning and Control so that working group which comprises of senior management technicians, supervisor, foremen, trade unionist, operations etc. have a common termination and set of ideas with which to analyse and discuss problems and install fruitful improvement.

3.2 THE PRODUCTION ORDER

The Production Planning which constitutes the paper work leads finally to be in issuing the production orders. This is evidently very tedious and complicated matter preparing the production orders but essentially to be maintained. Such system cannot be application to other industries "as it is" because it is having a bearing of various aspects like size, and nature of manufacturing unit. With appropriate modification to some what extent it can be copied down from other one.

Purpose :-

1. To pass information to everyone concerned.
2. To authorise.
3. To start the control system.
4. To provide basis data for evaluation of performance like schedule, quality and cost wise.

Procedure :- To formulate the production and

1. Obtain all specifications like drawings, materials quality, quantity.
2. Outline the alternative methods of production and fix up the best one.
3. Determination of sequence of operations using process chart.
4. Find out the operation time required.
5. Prepare operation sheet with above data.
6. Work out production master program.
7. Prepare route cards and operation sheet.
8. Check out the available time on machine and prepare schedule of timing of production.
9. Machine loading charts for work distribution.
10. Prepare job cards, materials requisition cards, tools and drawing requisition, inspection and all other belonging.

Process charts :-

A process chart shows all the operation and the inspections of the process or procedure in their time sequence and the material or parts entering the process. The process chart is usually drawn at the commencement of the investigation, because fact finding should proceed from examination of the whole factory.

ASME STD No.101, distinguishes between two types of process charts.

1. Operation process charts – Which constitute a general layout showing the principle operations and inspections, as well as the points at which the materials enters the process.
2. Flow process charts – Which represents a more detailed picture, describing the activities associated with materials, men or machines and which record the sequence of operations, transportations, inspections delays and storages that occur.

The Advantages of Process charting :-

1. It is convenient means of presenting overall information on a factory in limited space and is a record for future reference.

2. Detailed can be recorded on the chart in the factory when the job is observed, so that the chart reflects the mind of carrying.
3. It forces the analysis of work to be made in a quick and logical fashion according to (i) the sequence in which the work is done (ii) the materials or things which do the work (iii) the type of work done (iv) The relationship between several production flows.
4. It is used to explain proposals for rationalising work and improving methods to the parties concerned.

3.3 PRODUCTION MASTER PROGRAM

The prepare the production master program the operation process chart demonstration the final sequence of operation is required, the following figure shows as typical example of such program for the manufacturing product constituting eight sub-parts. After manufacturing the sub parts which will undergo various operation prior to final assembly. The program is based on the final delivery to be maintained and treated as zero base denoting the commencement of production by tails of the individual components on the charts by negative time units. Since master program, include the information about the type of machine required and time consumption of performance the operation in question. Such type of data is to be collected first after studying the manufacturing drawings of completion of programming, the effect of sequencing on final schedule will be available.

Case Study – The following are the sequence of operation.

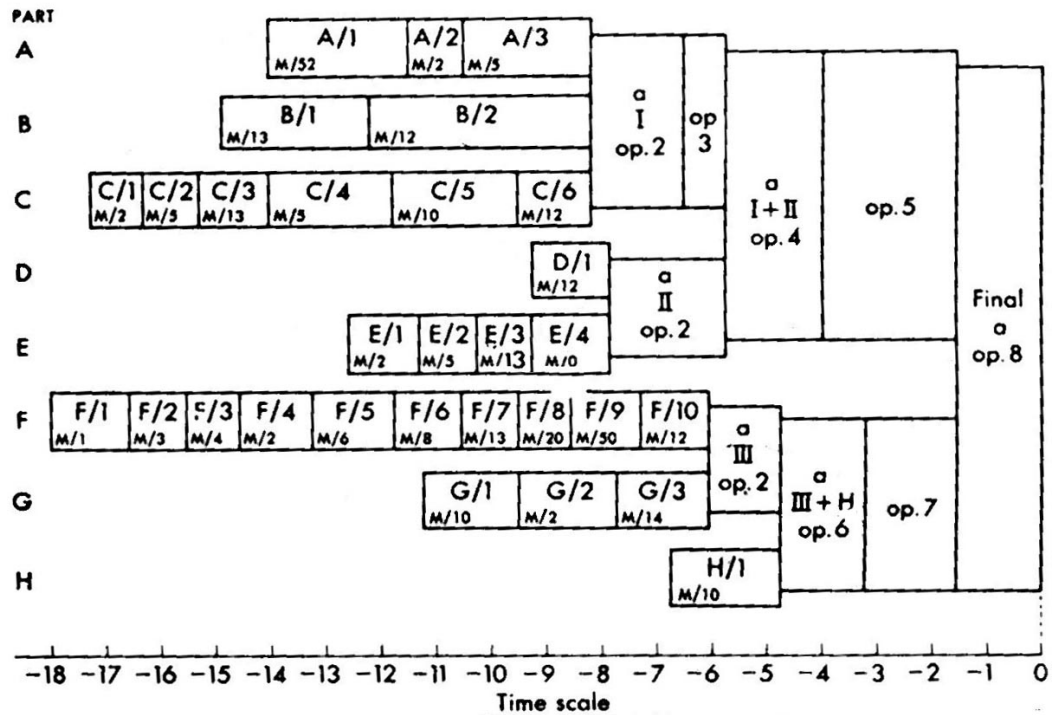
1. All parts are produced.
2. Parts are grouped in sub-assemblies.

I	A + B + C
II	D + E
III	F + G
3. Sub-assembly 1 is subject to an operation before further sub assembly
4. 1 + II
5. (I + II) is subject to an operation.
6. In the mean time, III + II are required
7. (III + II) is subject to an operation.
8. Final assembly takes place.

Notations :-

- A/1, A/2 etc operation required to produce part A
- M/52 - Machine on which operation A/1 is made.

- A - assembly operation
- Op - Refers to one of the operation

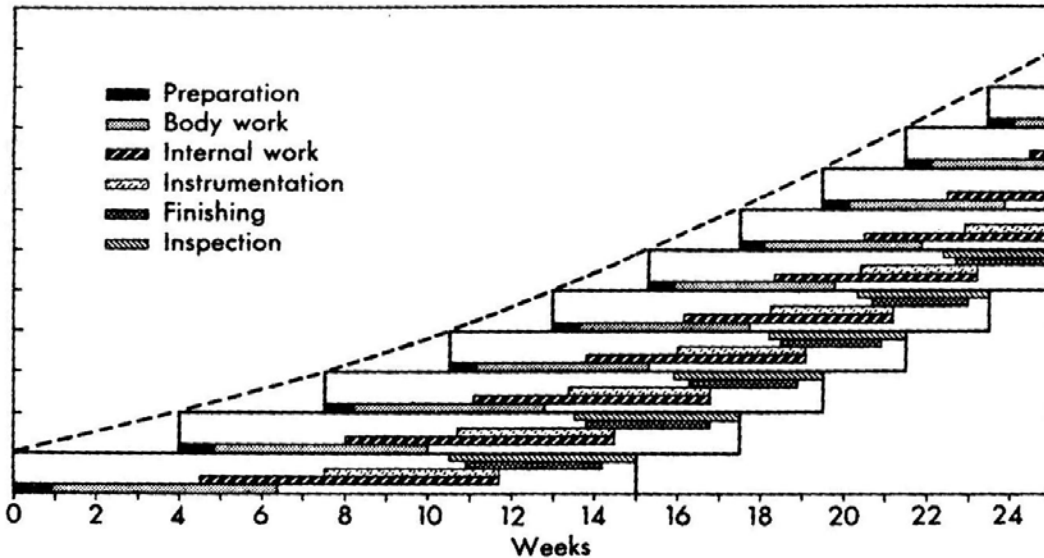


A PRODUCTION MASTER PROGRAM

3.4 PRODUCTION PROGRAM FOR LONG TERM PLANNING

The projects of quite a long time consumption like package units of boilers, cargo, and planes ship, building, sugar plants or and when special tooling and third party inspection is mandatory, production program for long term periods is to be prepared. The number of units to be undertaken can be governed by the number of cranes available, no. of rails for carries, no. of berths in ship building etc. Therefore, the quantity is limited by available capacity of plant and is the basis for preparing the production program and only those quantity of units will be started manufacturing concurrently. The first unit will be scheduled to come out of the production, taking into consideration the cycle time and special tools required. Tooling expenditure should lead the production program by a suitable phasing period.

Skilled & specialized team will not start the work on all units concurrently but the work is phased out suitably to utilize the capacity of machines and team to the optimum.



A 25 – WEEK PRODUCTION PROGRAM FOR AIRPLANES

3.5 PRACTICAL PROGRAM IN PRODUCTION PLANNING

On one side, We know sequence of operation with information about orders & for the product, on which production scheduled can be prepared. On the other side demand, operation that have to performed, kind of accuracy & skill they require manufacturing etc. determined the scheduling.

The accomplish above, We have man, machine, methods and money so that achieve and match all above resources with maximum possible utilization of 4 MTS. Therefore the problematic areas are

1. Quality - Batch wise quantity to be period and rate of manufacture
2. Allocation - of work of machine and men to given array of task.
3. Scheduling - to avoid clash of sequence of operation or interference of procedure.

All above are interconnected problems because, time depends on machine capacity and other commitments, while optimum schedule can be prepared only after these allocation. Therefore, before the advent of new batch production earlier production

sequence and schedule and prior commitment should be reviewed, delay in supply, break down in machine changes in market forecast on market demand and future (demand) trend in sales, all these will affect on schedule and its review is inevitable to achieve the maximum profit level.

3.6 QUANTITY IN BATCH PRODUCTION

Batch production is required when the rate of demand of product in the market is less than the rate of production or in other words, when the rate of consumption is less than continuous production rate. In view of matching both things, for some period, the production is stopped, during which the capacity of (unit) production line is utilized to produce the similar product or variety of goods in similar product or variety of goods in similar fashion. The interval between two production periods is called production cycle which thus can be organised, in which each product is manufactured in determined quantities, corresponding to the total demand for it, throughout the cycle time.

The best batch size or the production quantity is to be analysed for each product separately disregarding the effect of other products on scheduling to come up with the rate of demand. Secondly, the best master program for each product is to be set up to account of plant capacity and the effects of batch sizes on cycle time to achieve profit level.

Production cannot be continued with the potential demand without no stock, position. Minimum stock level is to be analysed and maintained looking into delivery lead time, during purchasing the material. There is simple inventory grapher plotted better level of the stock, Q against time (+)

Assume	a_p	-	Stock Building units/time
	a_c	-	Consumption, units/time
	$O-1$	-	Production process during which stock Q_1 is maintained with a uniform rate of a_p units/time
	$0-Q_4$	-	Stock level when production stop
	$1-2$	-	Variation in stock due to consumption at uniform rate of a_c units/time
	T_c	-	Consumption period

Same cycle will be repeated, unless it is decided to produce new lot of Q_3 , where in T_p & T_c period will differ, by the same proportion, from the corresponding values in preceding cycle.

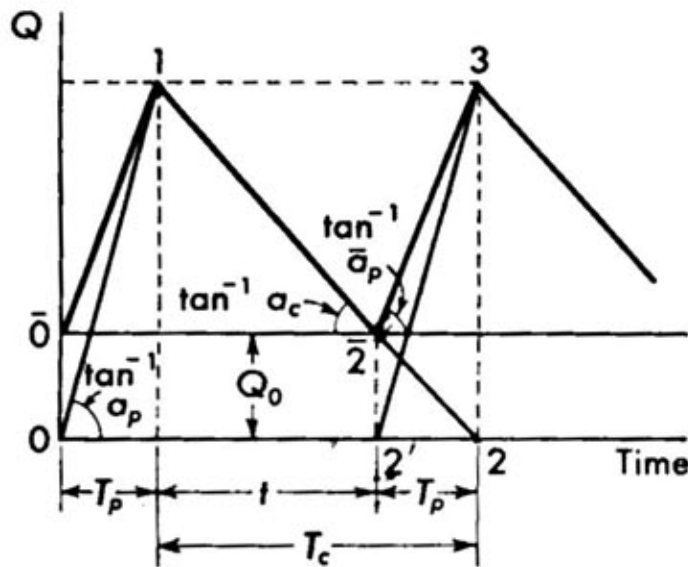
From Δ 012, it can be formulated that

$$Q_1 = \frac{ap T_p}{ac T_p} = \frac{ap}{ac} \quad \text{-----} \quad (1)$$

$$\frac{TP}{Tc} = \frac{ac}{ap} = V \quad \text{-----} \quad (2)$$

V is ratio which measure the amount of time spend on one product during cycle. When $V = Q_3$ no production is required or no time is required for production and is a problem of inventory only. In such orders given by stores are to be executed.

Now the fact is that the consumption is continuous and when the production will resumes, the stock will not be available to feed the customer and supply from store will be stopped unless production starts promptly. Therefore intimation is to be given for production well ahead the stock becomes zero. The safety margin of stock should be determined in such a way that stock will start building up to a pre-determined level at the completion of the production period.



STOCK CONTROL WITH A BUFFER STOCK

Instead of restarting production at 2, when old stock is fully consumed a new stock level at point 3, is required and therefore production must start at point 2 where 2-2' production time required for accumulation of stock denoted by point 3. So Q_0 is a stock below which stock level should not fail.

The other circumstances like setting time, additional delays, non availability of match & Machine etc., even production should start earlier at point 2'', accounting for this depend interval T_d , stock level Q is at order is at order point.

$\bar{ap} = ap - ac$, because of shifting of horizontal axis upward by distance Q

$$t = T_e T_p - is, \text{ interval time available for other product} \\ = T_e(1-V) - IS \quad (3)$$

$$Q_u = acT_p, \text{ safety - stock, from } \Delta \bar{2} - 2 - 2$$

$$\frac{Q_u}{Q} = \frac{ac}{ap} = V \quad (4)$$

As mentioned above, the actual stock level at which the order for production is given is higher than Q_u and from equation.

$$\frac{T_p}{T_e} \frac{ac}{ap} = V \quad \text{it can be show that}$$

$$\frac{Q_u}{Q} = \frac{T_p + T_d}{T_p} = 1 + \frac{T_d}{T_p} \quad (5)$$

If the delay period is negligible compared with the production period, the stock order point will be same, as the safely stock Q_u

A buffer stock is required to take care of possible stops or breakdowns in continuous production, whereas in batch production, the stock of each product have inevitably to be raised to a predetermined value prior to commencement of production of other items to low stock level will result into small batch and high set up cost/piece and high set up /piece from production point of view, high stock level is more desirable which lead to have carrying cost in the form of interest charges on capital investment, storage maintenance deterioration & breakage cost, the main factors affecting the selection of batch sizes to be summarised as under –

- 1) Consumption rate – ac
- 2) Production rate – ap
- 3) Set up cost of machines and sundry expenses to start run, s
- 4) Interest charges/piece/unit time
- 5) Average cost of storage including maintenance of stock, deterioration and breakages
- 6) Sales price – y
- 7) Production cost/piece – y

3.7 THE SELECTION OF BATCH SIZE

Depends under minimum total production cost/piece which yield maximum profit and best performance due to tough competition, the final sales price should be reduced to such an extent that production that production at minimum cost, leaving only marginal profits is an inevitable policy. But when the circumstances does not allow to produce the

product at minimum cost, other factors will be responsible to compute the optimum size. The following four criteria will decide the policy for the selection of batch size.

- 1) Minimum production cost/piece
- 2) Maximum profit for a batch
- 3) Maximum ratio of profit/cost of production (maximum return)
- 4) Maximum rate of return/unit time

3.8 MINIMUM – COST BATCH SIZE

The production cost/piece consist mainly of four factors.

- 1) Constant cost per piece, e , which include material m , labour, i and overhead cost.

$$C = m + I + O$$

- 2) Preparation costs, per batch which include drawings, planning, setting up of machines, equipment etc. Therefore, the cost per piece is S/Q .

- 3) Interest carrying cost paid on the money invest and in articles kept in stock.

$$I = i.e. \text{ for one piece/unit time.}$$

The average level of stock during consumption period, T_e , is $\frac{1}{2} (Q \& Q)$

$$\text{Carrying Cost} = I \left[\frac{(Q+Q)}{2} \right] T_e$$

But $T_e = Q / ae$, and dividing by Q

$$= \frac{1}{ac} \times \frac{(Q+Q)}{2} \times \frac{Q}{Q}$$

$$= \frac{1Q}{2ac} \left(1 + \frac{Q_u}{Q} \right)$$

$$= \frac{1}{2ac} \times Q(1+y)$$

- 4) Storage carrying cost, including changes for space and persons, maintenance while in stock deterioration and breakage. If the average storage cost/piece are B per unit time, then for the consumption period T_e , they are

$$B \times T_e \quad \text{or} \quad \frac{BQ}{ae}$$

Therefore, Total cost/piece = 1+2+3+4

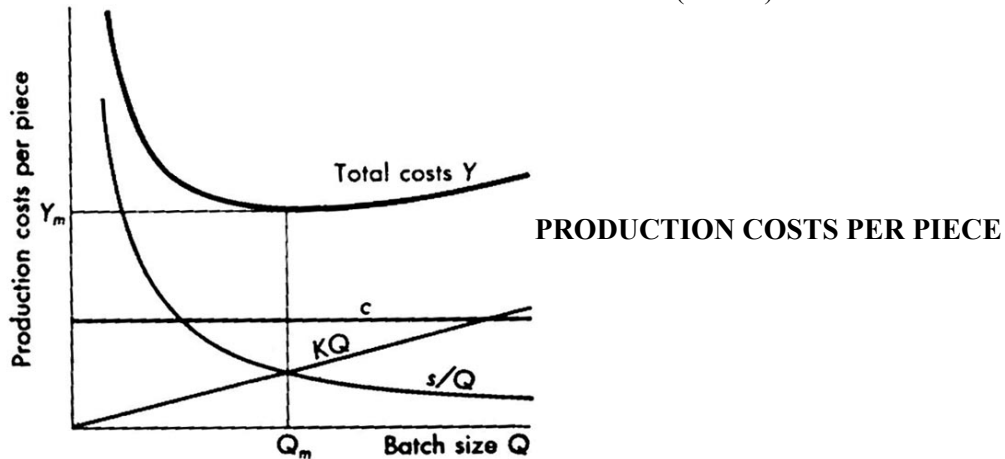
$$\begin{aligned}
 Y &= C + \frac{S}{Q} + \frac{1}{2ae} Q (1+y) + \frac{BQ}{ae} \\
 &= C + \frac{S}{Q} + \frac{Q}{2ae} \{I(1+y) + 2B\} \quad (6)
 \end{aligned}$$

$$Y = C + \frac{S}{Q} + KQ \quad (8)$$

Where $K = \frac{I(1+y)+2B}{2ae}$
 = Carrying Cost

Equation (8) is having linear term for carrying cost k, and hyperbolic term for preparation cost as the only variable features of the function. Therefore, claim or high accuracy is hardly justified. Moreover the batch production is a dynamic affair and circumstances may rapidly change.

Thus $Y = C + \text{Total annual variable cost (TAVC)}$



$$\frac{dy}{d Q_m} = 0 - \frac{S}{Q_m^2} + K$$

$$\text{or } Q_m = \sqrt{\frac{S}{K}} = \sqrt{\frac{2acs}{I(1+y)+2B}} \quad (9)$$

$$\text{or } \frac{S}{Q_m} = K Q_m \quad (10)$$

That is total carrying costs per piece and the preparation cost per piece are equal, When Q_m is produced, intersection of the two variable cost curves represents minimum cost/piece i.e., two terms of variable costs are equal at Q_m . Once the values of S & K have determined the curve of two variables are plotted to locate Q_m at the point of intersection which is more definable than the determination of minimum point on the shallow portion of curve.

The minimum total production cost / piece

$$\begin{aligned}
 Ym &= C + \frac{S}{Qm} + KQm \\
 &= C + \frac{2S}{Qm} - C + 2 KQm
 \end{aligned}
 \tag{11}$$

HARRIS – CAMP FORMULA

When the production period, T_p is comparatively short and storages changes, BTC or BQ / ae is small, a simplifies version of equation.

$$QM = \sqrt{\frac{2 a_c S}{1}}
 \tag{9(a)}$$

INVENTORY FORMULA

When production period, T_p is either relatively short,

$$QM = \sqrt{\frac{2 a_c S}{1+2B}}
 \tag{9(b)}$$

RAYMOND FORMULA

Late Raymond studied the effect of variables on batch size determination. He concerned with the effect by dividing a batch into number of lots and the time involved in waiting between operation. His simplified formula published in 1930 is as under –

$$QM = \sqrt{\frac{2 a_c S}{I \left[2F - V \left(1 - \frac{I}{N} \right) \right] + V \frac{2k}{A} + \frac{2b}{h} \left\{ I w \left(1 - \frac{I}{N} \right) \right\}}$$

Where, F = a stock coefficient, Ratio of the average number of articles in the stock above Q_0 to the maximum number above Q_0 , for uniform consumption,

$$F = \frac{I}{2}$$

$$C = \text{Cost of piece in progress} = m + \frac{I}{2}(L+O)$$

$$g = \text{Volumes storage space per piece}$$

$$K = \text{a factor to take account of Work in Progress} = \frac{C^I}{C} = \frac{I}{2} \frac{m+c}{C}$$

b = Storage costs per m^3 / unit time

h = Average height which storage is permitted

N = No. of lots in the batch

$$A = \text{Time factor} = 1 + (N - 1) \frac{(\text{Time for first operation in batch})}{(\text{Total process time for first lot})}$$

3.9 THE PRODUCTION RANGE

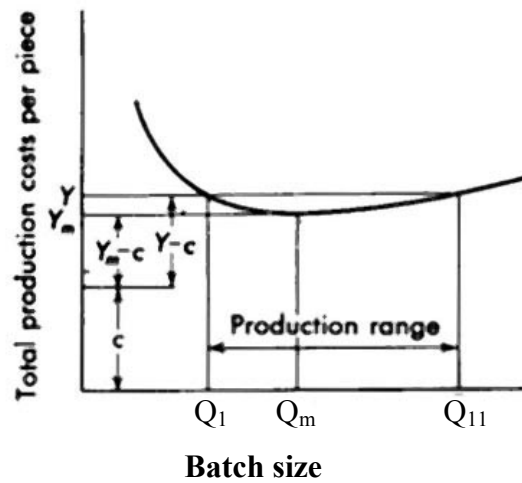
It can be well determined the minimum cost batch size which can be targeted for production. But in fact, the production schedule cannot be prepared satisfactory to have these ideal batches only.

Therefore, the batch size with 1 limit can be used to have the desired flexibility while attempting the scheduling of the batch. Naturally, total production cost per piece above the cost required while producing Q_m , is to be allowed. Then it is possible to deviate from Q_m to either side and select convenient batch size which will not increased in production cost y , above predetermined value.

In order to find the numerical value of two limits Q_I and Q_{II} , we shall first define a non-dimensional ratio p as under –

$$p = \frac{y - c}{y_m - c} = \frac{\text{Variable Cost}}{\text{Minimum Variable Cost}} \quad (15)$$

A convenient measure of increase in cost above Y_m



THE PRODUCTION RANGE

Function may be written as

$$\begin{aligned}
 Y &= C + (y - c) \\
 &= C + \frac{(y - c)}{(y_m - c)} \times (y_m - c) \\
 &= C + P(y_m - c) \\
 &= C + P \frac{S + KQm}{Qm} \\
 &= C + \frac{2Sp}{Qm}
 \end{aligned}$$

Find out QI & QII, we use

$$\begin{aligned}
 Y - C &= \frac{S}{Q} + KQ \\
 Y_m - C &= 2KQ_m \text{ and substitute in (15)} \\
 p &= \frac{S/Q + KQ}{2KQ_m} = \frac{1}{2} \left(\frac{S}{KQ_m} + \frac{Q}{Q_m} \right) \\
 &= \frac{1}{2} \left(\frac{Qm^2}{QQm} + \frac{Q}{Qm} \right) \left[\ominus \sqrt{\frac{s}{k} = pm} \right] \\
 p &= \frac{1}{2} \left(\frac{Qm}{Q} + \frac{Q}{Qm} \right) = \frac{1}{2} \times \left(\frac{1}{q} + q \right) \quad (18)
 \end{aligned}$$

$$\text{or } 2p = \frac{1+q^2}{q}$$

$$\text{or } q^2 - 2pq + 1 = 0$$

$$\text{or } q = p \pm \sqrt{p^2 - 1} \quad (19)$$

$$\text{or } QI = Qm \left[p - \sqrt{p^2 - 1} \right]$$

$$\text{and } QII = Qm \left[p + \sqrt{p^2 - 1} \right]$$

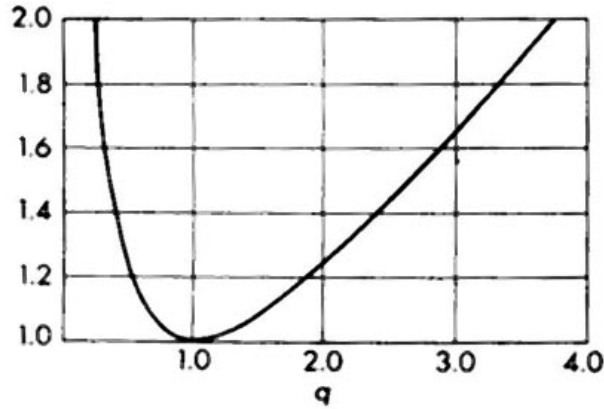
(20)

Equation (19) is a non-dimensional expression the tolerance on the production rate using dependant on the allowable increase in variable cost e.g.

When

P	Q1	Q11
---	----	-----

1	1			
1.01	.808	-13.2%	1.152	+15.2%
1.05		-27%		+37%
		-36%		+50%



DETERMINATION OF THE PRODUCTION RANGE

The desirable degree of flexibility in selecting batch size will be ascertained for the likely increase in variable cost, while scheduling the number products.

Effect of p on production cost

In earlier analysis c is neglected. But if, the ratio $\frac{\text{constant}}{\text{variable}}$ cost per piece is considered, the effect of p on y will be reflected. Hence the ratio $\frac{KQm}{C}$ is defined for a particular under given circumstances, then

$$\mu = \frac{C}{KQm} = \frac{C}{S/Qm}$$

Larger value of u the Y affected by p is

$$\frac{Y}{C} = 1 + \frac{2kQm}{C} P, \tag{21}$$

KQm is carrying cost/piece when Qm is produced.

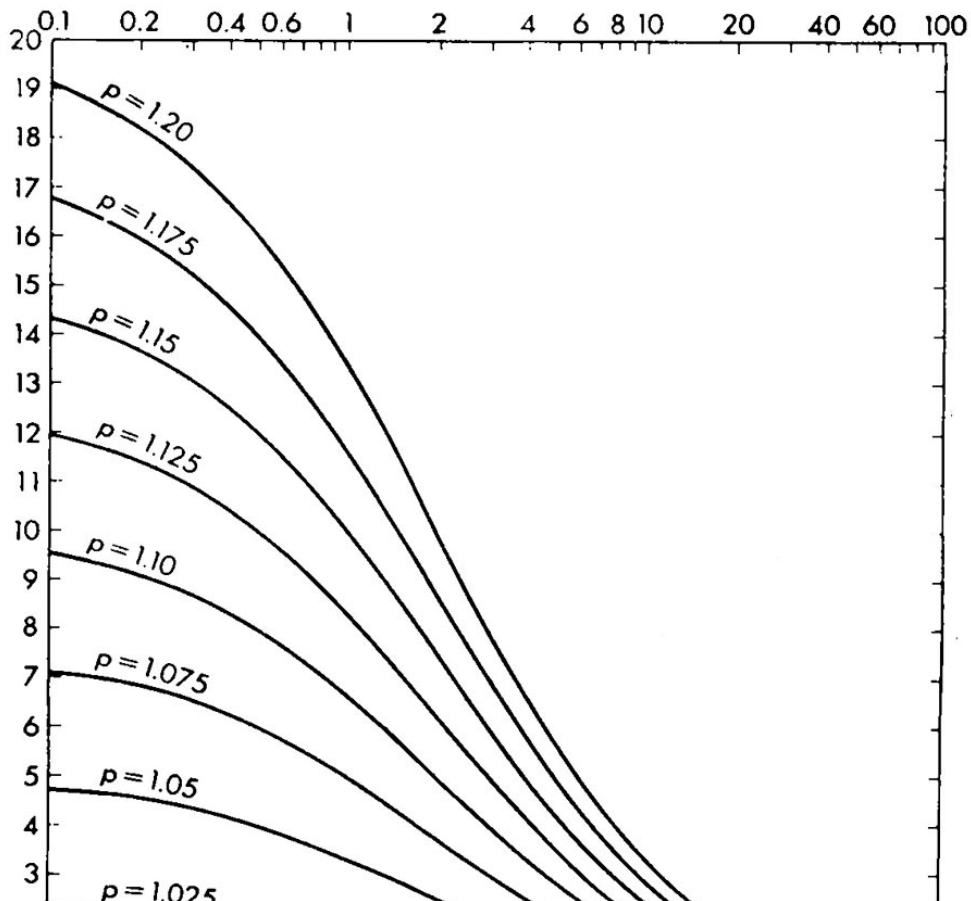
$$\text{Or } \frac{Y}{C} = 1 + \frac{2p}{u} \tag{22}$$

$$\text{Or } \frac{Ym}{C} = 1 + \frac{2}{u} \tag{23}$$

Increase in costs

$$\begin{aligned}
 \frac{\Delta y}{c} &= \left(1 + \frac{2p}{u}\right) - \left(1 - \frac{2}{u}\right) \\
 &= \frac{2}{u} (p-1) \quad \text{or} \quad \frac{p-1}{(1/2)u} \\
 \text{or } \frac{\Delta y}{Y_m} - \xi &= \frac{c(p-1)}{(1/2)u} \times \frac{1}{c(1+2/u)} \\
 &= \frac{p-1}{(1/2)u+1} \quad (24)
 \end{aligned}$$

When the ratio u is large, the slight increase in p is unlikely to cause a noticeable change in y , total production cost, thus leaving room for a wide production range to be defined, while when the ratio u is small, the reverse is the case. The graph stating the relation between ξ and u with p as a parameter is plotted as shown.



INCREASE IN COSTS PER PIECE

3.10 MAXIMUM PROFIT BATCH SIZE

It is a fact profit for whole batch is dependant on the no. of pieces in a batch. As total cost per piece rise slowly beyond Q_m , it is authenit to conclude that with marginal increase in Q_m will yield rise in profit. Too much rise in Q_m will release without profit or declination in profit per piece due to higher carrying cost.

If Q pieces are produced at the costs of y per piece and say that sales price is Y , the profit per batch is

$$Z = Q (y - y) \tag{25}$$

The profit is denoted by the shaded rectangle being the difference between money earn ($\square Y^1 Q$) and the cost of production ($\square Y Q$). The maximum profit is achieved

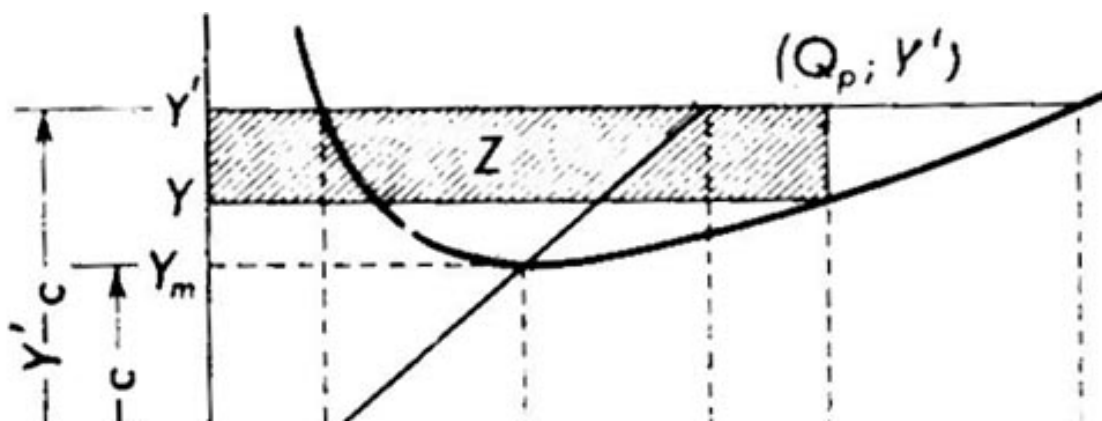
$$\text{When } \frac{dz}{dQ} = 0 = y^1 - \frac{d(Qy)}{dQ}$$

$$\text{Substituting } y^1 = C + \frac{S}{Q^1} + KQ^1 \text{ and } Y = C + \frac{S}{Q} + KQ$$

$$\text{Or } C + \frac{S}{Q^1} + KQ^1 - \frac{d}{dQ} (CQ + S + KQ) = 0$$

$$\text{Or } C + \frac{S}{Q^1} + KQ^1 - (2QK + C) = 0$$

$$\text{Or } \frac{S}{Q} + KQ^1 - 2 KQp = 0$$



BATCH PROFIT, SHOWN BY SHADED RECTANGLE.

Batch profit shown by shaded Area where Q_p is the batch size yielding max profit.

$$\begin{aligned}
 \text{Therefore } 2 \quad KQ_p &= \frac{S}{Q^1} + KQ^1 \\
 Q_p &= \frac{S}{2kQ^1} + \frac{Q^1}{2} \\
 &= \frac{Q_m^2}{2Q^1} + \frac{Q^1}{2} \\
 &= \frac{Q_m}{2} \left[\frac{Q_m + Q^1}{Q^1 Q_m} \right] \\
 Q_p &= Q_m p^1 \\
 \text{or } p^1 &= \frac{Q_p}{Q_m} = q \quad (27)
 \end{aligned}$$

as $p^1 > 1$ and therefore batch size giving maximum profit is larger than Q_m

Conclusion :-

- 1) Batch size should be more than Q_m to obtain maximum profit. Constant cost content is relatively high.
- 2) Set up time per piece is to be reduced.
- 3) Schedule become smooth and un-interpreted for a long time during which production methods are improved to save labour cost, materials and overhead.
- 4) If the methods are not improved or is not subjected to change, the higher production cost per piece will be incurred for Q_p .
- 5) If pricing policy is not fix, Q_p is not desirable.
- 6) Due to length stocking, turnover shows down of capital.

- 7) More money is required to produce Qp.
- 8) Large time to recover the profit.

3.11 MAXIMUM RETURN

The profit returned after making the investment for the production run of a batch may be poor or best. Such evaluation of performance does not depend only on the absolute figure of the profit. But it is linked with the figure of overall investment required. The ratio of the profit to the cost of the production run indicates the return n on the investment.

The cost to produce the batch is

$$\begin{aligned}
 \text{Qy and the return } \eta &= \frac{Z}{QY} = \frac{QY^1 - QY}{QY} \\
 &= \frac{Y^1}{Y} - 1 \quad (28)
 \end{aligned}$$

- Where Y^1 - Sales price per piece.
- Y - Production cost per piece

If Y and Y^1 are substituted by equation (22)

$$\begin{aligned}
 \eta &= \left(\frac{Y^1}{Y} - 1 \right) \\
 \text{The return} &= \left(\frac{u + 2p^1}{u + 2p} - 1 \right) \\
 &= \frac{(p^1 - p)}{p + (1/2)u}
 \end{aligned}$$

The return is maximum when $P = 1$

$$\eta \text{ max} = \frac{p^1 - 1}{1 + 1/2u} \text{ where } u = \frac{C}{KQm}$$

$$\text{efficiency index} = \frac{\eta}{\eta \text{ max}}$$

$$- \left(\frac{p^1 - p}{p - 1/2u} \times \frac{1 + 1/2u}{p^1 - 1} \right) \quad (30)$$

When η is active return with η max return when batch of Q is produced. The η will be affected by p, p^1 and u. Out of which η is more sensitive to $(p^1 - p)$

3.12 MAXIMUM RATE OF RETURN

The time factor is of great importance when turnover of the capital is considered. It would be desirable to achieve the same return, in a short period. A high rate of return can be achieved only if stock level is kept to minimum and replenished by small batch quantity. This batch size is termed as economic batch size which yields maximum rate of return and is much smaller than, Q_m , minimum cost batch.

Brief out the maximum rate of return and the empirical method suggested by FE Raymond and P1 Norton to compute Q_e ,

The smaller batch will entail higher production cost per piece, but this will require for less capital. Raymond proceeded to find this method by using his formula for Q_m . Modified by introducing f instead of 1, where the factor f proper conservation of capital as he put it, the value of f as suggested by Raymond is

$$f = 1 + 2 \frac{f}{l} + \frac{(f/i)^2}{[2(bf)/h][1-(1/N)]}$$

$$1 + \frac{2Ky}{A\{1-y[1-(1/N)]\}}$$

Where i - rate of interest paid on capital

f - rate of return on capital excluding interest rate.

The maximum rate of return yields somewhere at the middle of $Q_m - Q_e$. This batch can be computed by the same method except that the factor f is $f = 1 + 2r/l$

A similar method was advocated by PT NORTON, who presumes $1 =$ Total interest paid, as well as taxes, insurance etc.

The desired rate of return on capital

$$Q_e = \frac{2 Q_e S N}{(r+i)C + 2B(1-\lambda)}$$

Where N = Number of working days.

r = desired rate of return

i = taxes, insurance etc.

b = storage cost per piece per day

In this method

- 1) The interest is related only on the constant production cost, C and not to the total production cost, y
- 2) The desirable value for the rate of return can be selected.

In practice the fixed sales price is difficult to maintain and it depends on the following conditions.

- i) Conditions prevailing in the market.

- ii) Changes occur due to competition.
- iii) Preparedness on behalf of customer to pay
- iv) Batch size available

3.13 (ANALYTICAL METHOD) – ECONOMIC BATCH SIZE

The find rate of return in terms of sales price production cost and batch size

Rate of return $R = \frac{n}{Tc}$

$$\frac{1}{Tc} \left(\frac{Y^1}{Y} - 1 \right) \quad (31)$$

From equation (1) $Tc = \frac{Q}{ac}$, then

$$R = \frac{ac}{Q} \left(\frac{Y^1}{Y} - 1 \right)$$

The maximum rate of return is obtained when $\frac{dR}{dQ} = 0$

$$\text{Or} \quad - \frac{d}{dQ} \left[\left(\frac{Y^1}{Qy} - \frac{1}{Q} \right) ac \right] = 0$$

Dividing by ac and multiplying by Q^2

$$\frac{d}{dQ} (y^1 y Q - y^2 Q) = 0$$

$$\text{or} \quad y^1 \frac{d}{dQ} = (yQ) - y^2 \quad (32)$$

Now $\frac{d(YQ)}{dQ} = d \left[\left(C + \frac{S}{Q} + KQ \right) Q \right]$ from equation (8)

$$= d [CQ + S + KQ^2]$$

$$= C + 2KQ$$

$$\text{or} \quad y^1 (C + 2KQ) = \left(C + \frac{S}{Q} + KQ \right)^2$$

$$\text{or} \quad C^2 + \frac{S^2}{Q^2} + K^2 Q^2 + \frac{2CS}{Q} + 2SK + 2CKQ = y^1 C + 2KY^1 Q$$

Substitute $Q = Q_c$, for economic batch size

$$K^2 Q_c^2 - 2KQ_c e (Y^1 - C) + (C^2 + 2SK - Y^1 C) + \frac{2CS}{Q_c} + \frac{S^2}{Q_c} - 0$$

Multiply by Qe^2

$$K^2 Qc^4 - 2KQc^4(Y^1 - C) + (C^2 + 2SK - Y^1 C)Qc^2 + 2CSQc + S^2 - O \quad (33)$$

$$\text{Now } p^1 = \frac{Y^1 - C}{Ym - c} \quad \text{or} \quad (Y^1 - C) = P^1 2kQm$$

$$K^2 Qe^4 - (PKQm) 4KQe^3 + [(2SK) - (2p^1 KQm)e] Qe^2 + 2CSQe + S^2 = O$$

Divide throughout by $K^2 Qm^4$

$$\frac{Qe^4}{Qm^4} - \frac{4p^1 K^4 Qm Qe^4}{K^2 Qm Qm^4} + \frac{2Qe^2}{Qm^2} - \frac{SK}{K^2 Qm^2} - \frac{p^1 KQmC}{K^2 Qm^2} + \frac{2CSQe}{K^2 Qm^4 Qm} + \frac{S^2}{K^2 Qm^4} = O$$

Substitute

$$q = \frac{Qe}{Qm}, \quad u = \frac{C}{KQm}$$

Then,

$$q^4 - 4p^1 q^3 + 2 \left[\frac{S}{K} - \frac{1}{Qm^2} - \frac{P^1 C}{KQm} \right] q^2 + 2u - \frac{S}{K} - \frac{1}{Qm^2} - q + 1 = O$$

$$\text{or } q^4 - 4p^1 q^3 + 2(1 - up^1) q^2 + 2up + 1 = O \quad (34)$$

$$\text{or } 4p^1 q^3 + 2q^2 p^1 u = q^4 + 2q^2 + 2uq + 1$$

$$\text{or } p^1 = q^2 \frac{[q^2 + 2 + 1/q^2 + 2u/q]}{2q^2 [2q + u]}$$

$$p^1 = \frac{(2p)^2 + 2u/q}{2(2q + u)} = \frac{4p^2 q + 2u}{2q(2q + u)}$$

$$p^1 = \frac{2p^2 q + u}{q(2q + u)}$$

$$2p^1 q^2 + p^1 uq - 2p^2 q - u = O$$

$$\text{or } 2p^1 q^2 + (p^1 u - 2p^2) q - u = O \quad (35)$$

P is function of q in the quadratic equation. As p varies slowly with q the equation can be solved by stages. In first care, take $p = 1$ and then the correction is introduced for p by using equation (18)

It is finite in practice. If an extreme case is taken where u equation (35) reduce to

$$up^1 q - u = 0$$

$$\text{or } u(p^1 q - 1) = 0$$

$$\text{or } q = \frac{1}{p^1} \text{-----}(36)$$

when $u = 0$

$$2p^1 q^2 - 2p^2 q = 0$$

$$\text{or } q = \frac{p^2}{p^1} \text{-----(37)}$$

Therefore, the solution for q lies between the value obtained by equation (36) and (37) and, $Q_e = q Q_m$

Example

The minimum cost batch size is known to be 2000 pieces. Find Economics batch size when sales price yields a factor $p^1 = 1.4$

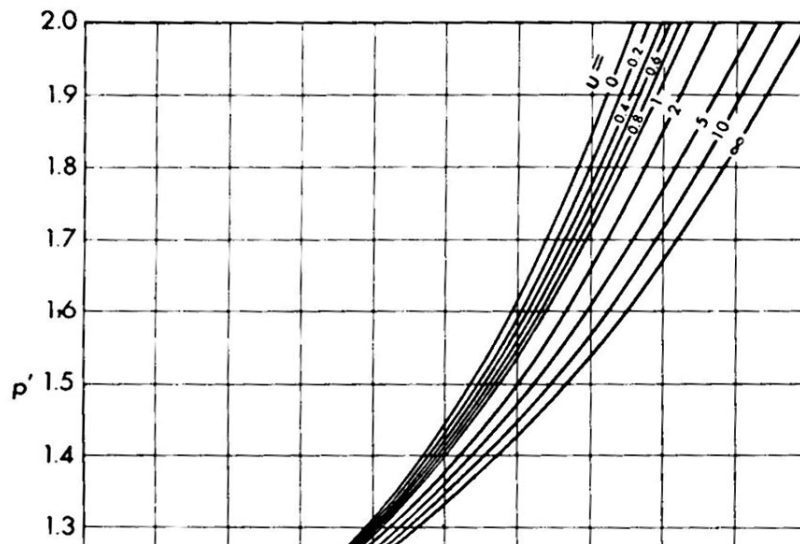
Solution:

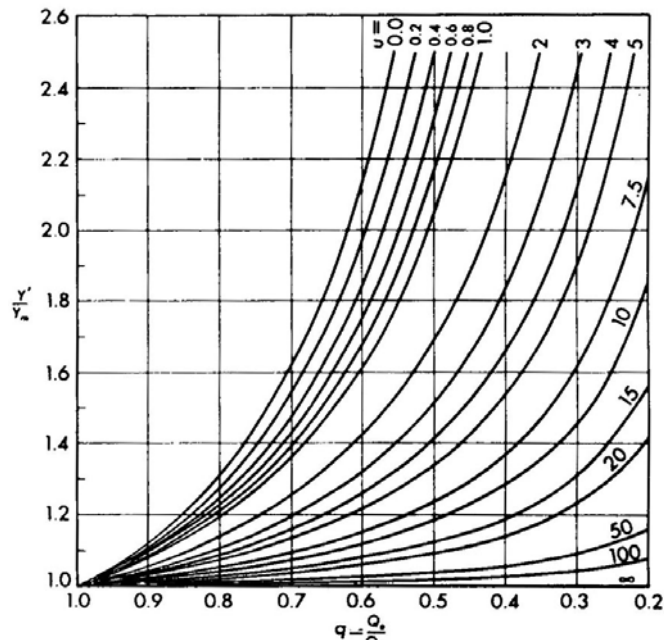
Step I	Step II	Step III
$q = \frac{1}{p^1} = \frac{1}{1.1} = 0.71$ $p = \frac{1}{2}(q+1)$ $= \frac{1}{2} - \frac{(.71+1)}{.71} = 1.06$ <p style="text-align: center;"><i>Corrected Value</i></p> $q = \frac{p^2}{p^1} = \frac{(1.06)^2}{1.4} = 0.8$	$-\frac{1}{2} \frac{(0.8+1)}{0.8} = 1.025$ $-\frac{1}{2} \frac{(0.8+1)}{0.8} = 1.025$ $\frac{(1.025)^2}{1.4} = 0.75$	$-\frac{1}{2} \frac{.75+1}{.75} = 1.04$ $\frac{(1.04)^2}{1.4} = 0.77$

This shows that the real value of q lies between 0.71 depending on the magnitude of u , if u is high – q will be nearer to 0.71, u is small to 0.77

Take $q = 0.73$, $Q_c = q$, $Q_m = 0.73 \times 2000 = 1460$ pieces

Another method for finding out Q_c is to plot a graph between p^1 and q with u as parameter. The curve will be non-dimensional lies between two limits where $u = 0, u = \infty$ is important, since it reflects on Q_m , when selling price increases.





NON-DIMENSIONAL CURVES FOR COMPUTING THE ECONOMIC BATCH

It is clear from both the graphs that lowering the set up cost, s will reduce the economic batch size, both because q becomes smaller, owing to reduction in u and because Q_m is smaller.

It is interesting to study the variations in rate of return when a batch size is selected convenient basis for comparison would be Q_m

$$R = \frac{n}{Te} = \frac{n}{Q} \times ae, \text{ When } Q_m \text{ is produced}$$

$$R_m = \frac{n_m}{Q_m} ac$$

$$\text{Hence } \frac{R}{R_m} = \frac{n}{n_m} \times \frac{Q_m}{Q} = \frac{n}{n_m} \times \frac{1}{q} \quad (38)$$

As $\frac{n}{n_m} < 1$, it is clear that the batches larger than Q_m will adversely affect the rate of return.

FEATURES :-

- 1] Less capital is tied up.
- 2] The cost function is steep and far more sensitive to batch size
- 3] Production time is reduced and does not imply to improve the production technique as in case of long runs. Set uptime increases. Non productive time increases.

COMPARISON OF THE VARIOUS IMPLICATION TO BATCH SIZE

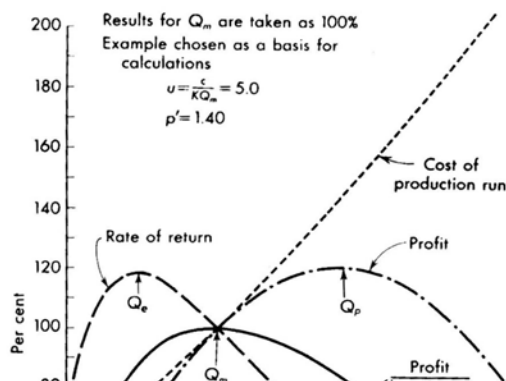
Presuming the results for Q_m as 100^0 au $5, p^1$ 1st the effect of batch size on

- i) Variable cost factor p , equation (18)
- ii) Production cost per piece, y
- iii) Cost per batch
- iv) Profit
- v) Profit/Cost of production
- vi) Rate of Return

Can be calculated as under and depicted on graph as shown

Effect of Selecting a lot size

q	p	y	Qy	$y^l - y$	$\frac{y^l - y}{Qy}$	R
0.5	1.25	107.1	53.6	18.8	35.1	70.2
0.73	1.05	101.4	74.1	63.9	86.2	113.4
0.8	1.025	100.7	80.6	75	93.1	116.4
1.0	1	100	100	100	100	100
1.1	1.005	100.1	110.1	108.6	98.6	89.6
1.3	1.034	101	131.3	119	90.6	69.7
1.36						
1.6	1.113	103.2	165.1	114.8	69.6	43.5
1.8	1.178	105.1	189.2	99.9	52.8	29.3
2	1.25	107.1	214.2	75	35	17.5



SOME EFFECTS OF SELECTING BATCH SIZES

3.15 EXERCISE

1. (i) Show that when a batch Q is produced, the ratio of profit to that which might result, if Q_m were produced is

$$\frac{Z}{Z_{mm}} = q \frac{p^l - p}{p^l - p}$$

(ii) When this ratio becomes a maximum

(iii) Given $p^l = 1.4$, plot the change of $\frac{Z}{Z_{min}}$ with q

Solution :-

$$Z = Q(y^l - y)$$

$$Z_m = Q_m(y^l - y_m)$$

$$\frac{Z}{Z_m} = \frac{Q}{Q_m} \frac{y^l - y}{y^l - y_m} = q \frac{y^l - (C + 2kQmp)}{y^l - (C + 2kQm)}$$

$$pt = \frac{y^l - c}{y_m - c} \quad \text{or} \quad p^l(y_m - c) - y^l - C$$

$$\text{or} \quad \frac{Z}{Z_m} = q \frac{p^l(y_m c) - 2KQm.p}{p^l(y_m - c) - 2KQm}$$

$$p^l - \frac{2KQmP}{(y_m - c)}$$

$$\text{or} \quad q \frac{p^l - \frac{2KQm}{(Y_m - c)}}{p^l - \frac{2KQm}{(Y_m - c)}}$$

$Y_m = C + 2KQ_m$, substituting

$$\text{or } \frac{Z}{Z_m} = q \frac{p^1 - p}{p^1 - 1} \quad (i)$$

When P = 1, Zm will be maximum (ii)

2. *A product for which it is know that u = 4 is produced in a quality which result increase of 6% of the variable costs above the minimum. What increase of total cost.*

Solution :

I Method

II Method

$$K = 1.06 Km$$

$$\frac{C}{KQm} = y_4 = C + 2K Qm$$

$$Ym = C + 2 Km Qm$$

$$= \frac{4}{0.12} + \frac{2}{0.12}$$

$$= \frac{6}{0.12} = 50$$

% increase in total cost above Ym

$$= \frac{1}{50} \times 100 = -2\%$$

$$P = \frac{Y - C}{Ym - C} = 1.06,$$

The increase in the production cost, due to deviaion from Qm

is given by

$$\xi = \frac{P - 1}{1/2u + 1} = \frac{1.06 - 1}{2 + 1} = \frac{0.06}{3}$$

$$\% \xi = 2\%$$

Prove that Qe is smaller than Qm

$$\frac{d}{dQ}(YQ) = C + 2 KQ$$

$$= y - \left(\frac{S}{Q} - KQ \right)$$

Hence Substitute in (32)

$$Y^1 = \left[Y - \left(\frac{S}{Q} - KQ \right) \right] = Y^2$$

$$\text{or } Y^r = Y - \left(\frac{S}{Q} - KQ \right) = Y^2$$

Since $y^r > y$ it follows that

$$\frac{S}{Qe} > KQe$$

as already shown, at the point of minimum cost

$$S = \frac{KQm}{Qm}$$

$$\text{or } \frac{S}{Q} < KQ \text{ for } Q > Qm \text{ and } \frac{S}{Q} > KQ \text{ for } Q < QM$$

Hence Proved.

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4. MACHINE CAPACITY

INTRODUCTION

The industrial revolution resulted in to the major changes in the technical conditions of production processes, established with the physical capacity of the operators. Earlier, there were flexible relationship between attendant and his machines. Mass scale production cultivate the structure of jobs and the related work processes. The proper division of work, machines, processes etc. has come into picture to measure the rating of production and productivity concept has been conceived.

The idle time means the unproductive period and naturally the relation of attendant with machine has to be synchronized to achieve the maximum output. The exercise of machine loading is to be excentated for fixing up the quantities of product to be undertaken for manufacturing, by observing the definite quantity of orders or by computing batch size. To accomplish the task the basic data like.

1. The breakdown of operations and sequence of operations.
2. The period of production run.
3. The type of processes involved, and
4. The available machines.

are required, in addition to the operation sheets. Therefore this is an assignment for the production engineers, after the receipt of the production program will be displayed in the graphical form, calls as bar chart, demonstrating the target period to produce the product. Machine leading is to be prepared in view of the above requirement taking into consideration

the capacity of the machines. This information will be separately carries on machine loading card individually, indicating the condition and capabilities with main specifications of machine, the prior commitment etc.

This chapter deals with the work analysis of operator with machines i.e. The relationship between productivity and nonproductive time, the assessment time, the assessment of the processes, process or machine capacity, the relationship between machine capacity and plant capacity, the factors impeding the machine output etc.

3.2 MACHINE OUTPUT :

The machine output is nothing but the rate of production in number of pieces per unit time. Generally, the machine output is restricted to mass production by ordinary machines, automatic or semiautomatic machines where the sequence of operations are in definite form. Therefore, machine output is inversely proportional to (unit) time cycle.

$$\text{Output of machine} = \frac{I}{\text{CycleTime, in minutes}}$$

$$\text{Or } Q_m = \frac{60}{T}, \text{ number of units produced hour ----- (1)}$$

Where Q_{Tu} = Theoretical machine output

T = Cycle time of production in minutes.

In other words, the max output of machine is obtained when the cycles time is optimum (minimum possible) and when the further reduction in process cycle time is not possible. This can be applicable, even if, the operator is handling more than one machines and the idle time of machine is preferably zero during cycle time. Sometimes, this can be achieved by altering the sequence of operations. The length of the cycle time is constituted by the attendance period add machine working time. Thus the cycle time is determined by the total activity time, even through, the concurrent activities by single operator exists.

This can be elaborated as under –

If, T, cycle time = 0.2 min (unloading) + 0.6 min.

(Inspection) + 0.3 (min) loading + 0.7 min (M/c running) + 0.2 (min) (Walking between m/c) = 2.0 minutes and the theoretical output would be.

$$Q_m = \frac{60}{2} = 30 \text{ units per hour}$$

Say, the inspection activity can be diverted to some-other supervisor, then the cycle time can be shortened by 0.6 minutes to 1.4 minutes, and the theoretical output

$Q_m = \frac{60}{1.4} = 42.8$ units per minutes. Now further curtailing of process cycle time is only possible, if the period in loading, unloading and machine is possible.

If, we think of activity chart, the various periods involved can be classified as under:

1. Independent Activity, l
2. Concurrent Activity, a
3. Idle time, i

The idle time may be of machine in or operator, i.e. The independent activity means the activity which is not dependent on machine or the activity of each partners not dependent or each other i.e. Machine & operator. Concurrent activity means the activity can be performed by more than one partners, each of which is contributing, his time and efforts to achieve the worth object. Idle time denotes that the partner is awaiting to other to complete his task.

The cycle Time, $T = a + t + im$,

If $im = 0$, then $T = a + t$

In every case, attempt is to be made to reduce the cycle time to minimum, and this can be achieved generally by the following Methods :-

1. **ENSURE** no idle time for partner of longest activity by
 - i) Changing or altering the sequence of various tasks
 - ii) Eliminating delays and stoppages at the end of every cycle.
2. **REDUCE** : The independent activity time by
 - i) Increasing the running speed of machine, rate of feeding, better cutting tools & lubrication etc.-
 - ii) Selecting the machine of improved design of the existing machines in better conditions.
 - iii) Transfer of part of operation to the other machines and appointing another operator to take care of part operations.

REDUCE : The concurrent time by

- i) Using better gigs for feeding, loading, setting, inspection etc. or better methods.
- ii) Starting the machine operation and then performing the preparatory task.
- iii) Using automatic unloading systems.

In spite of all above exercise, in actual practice, the output tends to fall down below the theoretical output, Q_{Th} due to various things like delays between cycles, necessary adjustment, repairs, sudden breakdowns, improper too and tacklets failures in power supply etc.

Therefore,

$$Q = \infty Q_{Th}, \text{ Where } Q < \infty < 1$$

Where ∞ is a coefficient that describes quantitatively the discrepancy between the theoretical and actual output liters.

3.3 MULTI MACHINE SUPERVISION BY OPERATOR :

In modern, days the machines are either automatic or semi automatic and sometimes with the automatic loading and unloading attachment and therefore a limited amount of attention is required on such as loading, unloading, inspection, setting and minor adjustments during operation. Therefore, it is quite possible to put more than one machine under the supervision of one operator. The machines and the operator becomes work centre and operator attends all machines in accordance with certain determined sequences which ensure maximum possible utilisation of production cycle. Just like, in the operation of handlonas, the operator is working with predetermined sequence of operation and whenever required the some operator is attending the break of threads also.

For further elaboration, consider a typical example that an operators is busy in loading (0.3 min) and unloading (0.2 min) between 2 minutes of operations of machine. Thus the operators is busy for $\frac{1}{4}$ times of complete operation cycle of 2 minutes. Now, the question remains that how many machines can be attended by operator. If we assign two machine operator becomes idle for 1 minute and if 5 machines are allocated, then machine become idle for 0.5 minutes i.e. Quarter of cycle time. Therefore with 4 machines perfect matching will be obtained and no idle time being incurred with on the part of operator or the machines.

But perfect Machining is not always possible. However, if the case of perfect matching is considered, then machine time is t and the preparation time (preparatory work) is 'Q', $T = a + t$, then, number of identical machines that can be attended by one operator.

$$n^l = \frac{a+t}{a} \text{ ----- (2)}$$

But during the case of not perfect matching i.e. when n , is not an integer and we have to select either (n) or $(n + 1)$ m/cs where $n < n^l < n + 1$ and the choice between n and $n+1$ machines would be governed by cost analysis of the operation.

C_o = Cost of labour per operator hr.

C_m = Cost per m/c per hr.

n = ng of m/s selected

Total cost per hr. = $C_o + n C_m$

$$\text{Output per m/c, } Q = \frac{60}{a+t}, \text{ units per hr.}$$

$$\text{The cost per unit, } Y_n = \frac{\frac{Co+n Cm}{60 \times n}}{(a+t)}$$

$$\text{Or } Y_n = \left(\frac{Co}{60n} + \frac{n Cm}{60n} \right) T = (a+t) = \left(\frac{Co}{Cm} \times Cm + \frac{ncm}{60n} \right) T$$

$$\text{Let } \epsilon = \frac{Co}{Cm} = \frac{\text{labour cost per hour}}{m/c \text{ Cost per hr.}}$$

$$\text{Then } Y_n = \frac{Cm}{60n} (\epsilon + n) T$$

Where, Y_n is the cost per unit when n m/cs are chosen and $E = Co/Cm$, is the ratio between labour and machine running costs.

When $(n + 1)$ machines are chosen, the total costs of the operation is $Co + (n + 1) Cm$. Now, the cycle time is $(n + 1) a$ since the operator is fully occupied and the machine have to wait their turn until his services become available. The output per machine is $60 / (n + 1) a$, units per hr. and the costs per unit is therefore,

$$\left(\frac{(Co + (n+1) Cm)}{60} \right) \frac{1}{(n+1)a} = \left[\frac{Co}{60/a} + \frac{(n+1) cm}{60/a} \right]$$

$$Y_{n+1} = \left(\frac{Co}{60(n+1)} + \frac{(n+1) Cm}{60(n+1)} \right) a(m+1)$$

$$Y_{n+1} = \left(\frac{\frac{Co}{Cm} \times Cm}{60(n+1)} + \frac{(n+1) Cm}{60(n+1)} \right) a(m+1)$$

$$= \frac{Cm}{60(n+1)} \times (\epsilon + n + 1) a(m+1)$$

$$= \frac{Cm}{60(n+1)} \times (\epsilon + n + 1) \times (n+1) a$$

$$= \frac{Cm}{60} \times (\epsilon + n + 1) \times a \text{------(4)}$$

$$\frac{Y_n}{Y_{n+1}} = \frac{Cm}{60n} (\epsilon+n) T \times \frac{60}{Cm (\epsilon+n+1) a}$$

Hence,

$$= \frac{(\epsilon+n)T}{(\epsilon+n+1)na}$$

Let

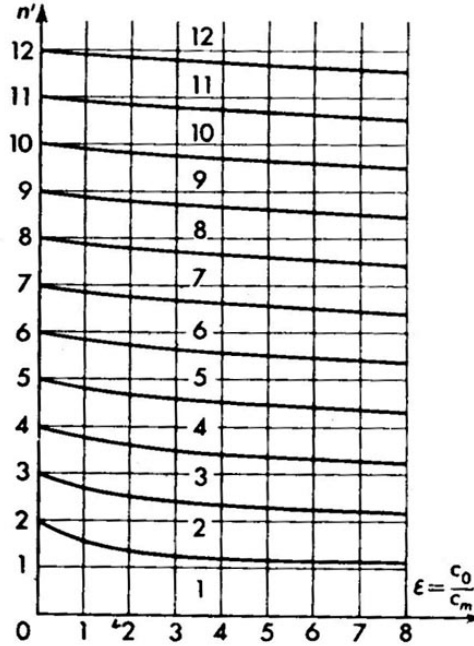
$$= \frac{T}{a} = n^l$$

Then,

$$= \frac{Y_n}{Y_{n+1}} = \frac{\epsilon+n}{\epsilon+n+1} \times \frac{n^l}{n} \text{ ----- (5)}$$

Hence $\frac{Y_n}{Y_{n+1}} > 1$, Choose $(n+1)$ machines
 < 1 , Choose (n) machines

On the above discussion, and deterministic conditions, the allocation of machine to one operator, when $Y_n/Y_{n+1}=1$, can be depicted as under –



**ALLOCATION OF A NUMBER OF MACHINES TO ONE OPERATOR
(UNDER DETERMINISTIC CONDITIONS)**

Where n^l is plotted against ϵ with n as a parameter, so that for known values of n^l and ϵ the number of machines to one operator can be found out. The curve is rather flat which means that the solution is quite insensitive to changes in ϵ . This can be described further from the following numericals, say

$$\varepsilon = 0.8$$

$$a = 1.2 \text{ min}$$

$$T = 6.9 \text{ min}' - a + 1$$

$$n^I = \frac{T}{a} = \frac{6.9}{1.2} = 5.75 \text{ then select } n \text{ } 5$$

But 6 machines can be selected when $\varepsilon = 5.5$

3.3.1 AMOUNT OF RELATIVE IDLE TIME :-

The selection of n or $(n + 1)$ m/cs can result into relative idle time, which amount can be calculated as under operator idle time $i_0^0 = (\text{cycle time}) - (\text{Operator time})$

$$\frac{i_0}{T} = T - na$$

$$\begin{aligned} \text{Or} \quad &= \frac{T - na}{T} = 1 - n \frac{a}{T} \\ &= 1 - \frac{n}{n^I} \end{aligned}$$

When $(n + 1)$ machines are chosen, operator is fully busy and idle machine time exist.

$$i_m = (n + 1)a - T / \text{per each cycle}$$

$$\begin{aligned} \frac{i_m}{T} &= \frac{(n + 1)a - T}{T} \\ &= (n + 1) \frac{a}{T} - 1 \\ &= \left[1 - \frac{(n + 1)}{n^I} \right] \end{aligned}$$

These two expressions can be methodically continue together into general equation.

$$\frac{i}{T} = 1 - \frac{n}{n^I} \text{ ----- (6)}$$

if $n \leq n^I$ M/cs taken, $i \geq 0$, is the operator idle time

if $n \geq n^I$ m/cs are taken, $i \leq 0$, is the machine idle time.

This can be represented on graph when n machines are assigned to operator, what will be time, as under :-

Now all above analysis does not cover for so many noteworthy factures like :-

- i) Inspection of machine
- ii) Inspection of the product

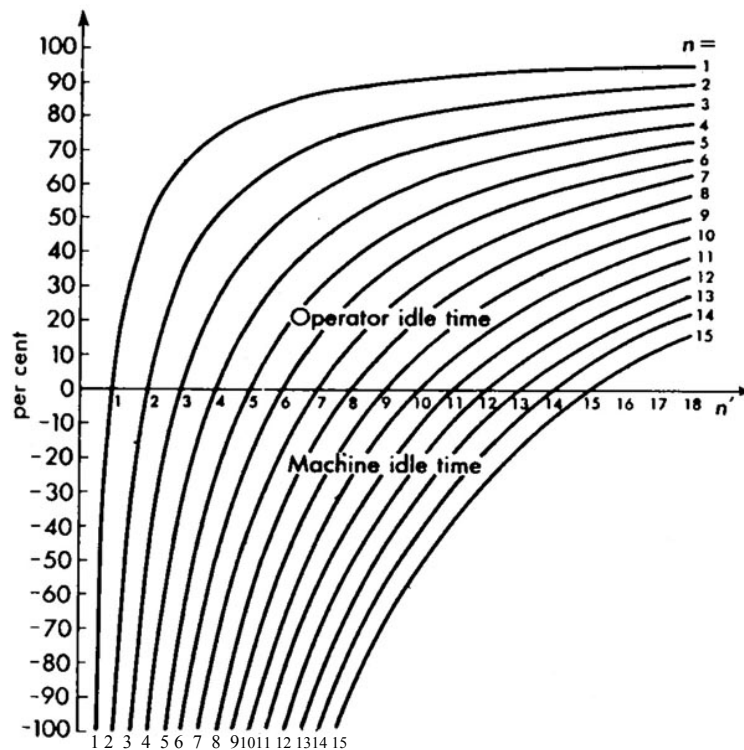
iii) Subsequent work for product like removing machine marks polishing, greasing matching or assembling several components.

iv) Talking

v) Movement of product from machine of production centre and again to machine.

vi) Personal allowances like relaxation etc.

3] Machine interference :- When practicing the cycle time due to random changers, machine will interface with each other. All above allowances will increase the independent time & output will be hampered to great extent.



RELATIVE IDLE TIME WHEN ASSIGNING N MACHINES TO ONE OPERATOR

3.3.2 MULTI MACHINE SUPERVISION CONSIDERING OPERATOR ALLOWANCES

Suppose the above maintained allowances for operators independent activity is b minutes for machine. Then the operator's activity per m/c = $(a + b)$ and machine work cycle = $(a + t)$

Hence, The number of machines for perfect matching

$$n = \frac{a+t}{a+b} \text{ ----- (7)}$$

a = Preparatory work (preparation time)

t = Machining time

n = No. of machine

b = Operator independent activity in minute.

When n is not an integer is neighbouring whole numbers may be considered, like $m < n^1 < n + 1$

The chose between n and $(n + 1)$ machines will be governed by cost consideration.

Therefore, Let C_u = Cost of labour per hr.

C_m = Cost per m/c running hr.

n = No. of machines selected

Total cost per hour = $C_o + C_m$

Output per machine, $Q = \frac{60}{(b+a)+t}$ Unit / per hr.

Cost per unit $Y_n = \frac{C_o + n C_m}{60 \times n}$

$$Y_n = \frac{\frac{C_o}{60n} + \frac{n C_m}{60n}}{a+b+t} T \quad [wT = a+b+t]$$

Substituting $\epsilon = \frac{C_o}{C_m}$

$$Y_n = \frac{C_m}{60n} (\epsilon + n) T \text{ ----- (8)}$$

Similarly, for $(n + 1)$ machines :-

The total cost operation = $c_o + (n + 1) C_m$

Cycle Time, $T = (n + 1) (a + b)$

Output per machine, $Q = \frac{60}{(n+1)(a+b)}$ Units per hr.

$$\begin{aligned}
 \text{Hence Cost per Unit, } Y_{n+1} &= \frac{C_o}{60(n+1)} + \frac{(n+1)C_m}{60(n+1)} T \\
 &= \frac{C_o}{C_m} \times C_m + \frac{(n+1)C_m}{60(n+1)} T \\
 &= \frac{C_m}{60(n+1)} \times (\epsilon + n + 1) \times (n+1)(a+b) \\
 &= \frac{C_m}{60} \times (\epsilon + n + 1)(a+b) \text{ ----- (9)}
 \end{aligned}$$

Therefore,

$$\begin{aligned}
 \frac{Y_n}{Y_{n+1}} &= \frac{C_m}{60n} (\epsilon + n) T \times \frac{60}{C_m(C + N + 1)(a+b)} \\
 &= \frac{(\epsilon + n)}{(\epsilon + n + 1)} \times \frac{T}{(a+b)} \times \frac{1}{n} \\
 &= \frac{\epsilon + n}{\epsilon + n + 1} \times \frac{n}{n} \text{ ----- (10)}
 \end{aligned}$$

Which is same as equation (5), except that using

$$\begin{aligned}
 a_l &= \frac{a+t}{a+b} \text{ as per equation (7) instead of} \\
 &= \frac{a+t}{b} \text{ ----- (2)}
 \end{aligned}$$

3.3.3. AN OPERATOR WITH NON-IDENTICAL MACHINES :-

The non-identical machines will have different cycle time, including loading, operator with machine, the following conclusions will withstand.

To avoid machine idle time, im, the cycle time of each machine must be equal and longer than operator’s work cycle

$$\begin{aligned}
 \text{eg. } T_1 &= T_2 = T_1 \\
 a_1 + T_1 &= a_2 + T_2 = a_3 + T_3
 \end{aligned}$$

$$\text{or } T_1 \text{ Cycle time} \leq a_1 + a_2 + a_3$$

To avoid operator idle time, i₀₃ the attendance time of all machines should be greater than work cycle time,

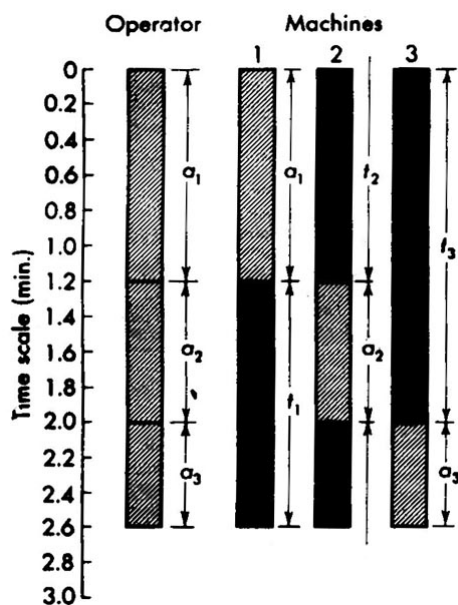
$$\text{eg. } a_1 + a_2 + a_1 \geq T$$

Hence, from above, to leave an perfect matching for ‘n’ number of non-identical machine’s with single operator, we must have

$$T_1 = T_2 = \dots = T_n = \sum T_n$$

The following example demonstrate by assigning three non-identical machines under a care of single operator, for perfect matching, with the help of man-machine chart.

In case of imperfect machining the selection of number of machines n or $(n + 1)$ depends upon the cost per hour. Consideration which include machine running cost per hour. Plans operator cost per hour. Therefore, in case of n machines, the operator is idle part of time $(T - n a)$, minutes per cycle and in case of machine idle time $(n + 1)a - T$, min. per cycle, will hold for the selection of $(n + 1)$ machines under single operator.



Assigning three nonidentical machines to operator for perfect matching between operator and

3.4. MACHINE INTERFERENCE :-

If you consider the machine cycle with deterministic operations, the output of work centre will increase linearly with number of machine and cycle time $T n a$

The rate of failure and failure time have fairly less time in automatic machines, as compared to operation time and less time of attention required to provide. Whereas, in case of semi-automatic machines, the attendance time a , is more. Naturally, machine remains idle when the operator is busy in attending the other machine for servicing. Such situation

where man and machines are dependent and awaiting for each other : is called 'INTERFERING' operator is interfering with machine due to his busy schedule for other machine leads to the production rate. The attention time depends on the type of repair or service invited.

Similar resemblances occur where ---

1. Operator
2. Customer buying stamps for sending parcel.
3. Number of aeroplanes tries to land on port.
4. Cargo ships waiting for berth.
5. Retailer is attending the customer more than one.

In each case mentioned above, where is a random arrival of customer inviting attention at a time and therefore scheduling or Queue is required to form to avoid the bottle-necking of work. In case of assignment or shouldering of a semi-automatic machine to single operator, the interference increase not only with the number of machines but also with the proportion of attention time received per cycle. Thus at increases interferences increases and output starts reducing.

3.5 THE ASHCROFT TABLES :-

Mr. H. Ashcroft had done the excessive research work on the productivity of several machines under the supervision of single operator. The tables are prepared for n number of semi-automatic machines and known ration of, $\frac{a}{t} = p = \frac{(\text{Attention time})}{(\text{Machine time})}$

For finding out efficiency of machine and their output.

So as to compute the above exercise, he made the following two major assumptions :

1) Random stopping and attention :-

He presume that the probability of stopping after removing the cause of breakdown, the next breakdown suppose to occur is independent of time.

2) Constant service time :-

The service time required for each machine is constant.

Both above assumptions made of author Mr. H. Ashcroft is impracticable. Because operator will expect to have smooth running of machine after repairment atleast for satisfactory period and therefore the frequency of breakdown should be directly dependence on running time of machine. On the other hand, if the frequency of stoppages increases, the

constant service time of operator is meaningless. Thus due to invalid justification for above two assumptions, the Ashcroft tables becomes, incompatible.

In spite of all above, it has been found that the tables gives approximation in most of the cases even satisfying the assumptions of Mr. II. Ashcroft.

Therefore, pre-summing random stoppages and failure or next stopping of machine independence of last attention made by operator, the probability of smooth running of semi-automatic machine over a period of $t = -kt$, where k is coefficient depending on number of machines under a care of one operator.

In second case, if two semi-automatic machines are working under an operator, output which one is running while another is being attended, the probability of machine to continue.

$$= e^{-p}, \text{ Where } p = \frac{a}{t}$$

The probability of stopping second machine = $1 - e^{-p}$, because the probability of two independent events is unity. Here, the second machine must be either running or stopping, the probability of the two events occurring has to be unity.

3.6. AVERAGE NUMBER OF CONSECUTIVE SERVICING TASKS :-

These are the probable attempts of servicing to be made on the automatic machines under a care of single operator & where the sequence of operations are deterministic conditions.

Case 1 :- Where two machines are under one operator, being two machines, the attempts of servicing on an average will be two numbers during one chain of consecutive servicing task (ANCST) x 2 for the following two situations can be determined as under :-

	M/C A		Task	M/C B		Probability
	Stop	Running		Stop	Running	
Situation1	S	---	First	---	R	Always
Situation2	---	R	Second	S	---	$(1-e^{-p})$
Chain is Terminated	S	---	Third	---	R	Always
And so on.....						

Now, Since the stopping of machine is Random and independence of time after last attention ANCST

$$= x \text{ Situation 1} + \text{Situation 2}$$

$$= 1 + x 2 (1 - c^{-p})$$

or $x_2 = cp$

Case 2 :- Where there are three machines under a care of single operator. In this case there will total 4 number of situations as under .

Additional ANCST = Situation (1 + 2 + 3 + 4)

$$x^3 = 1 + x_2 (1 - e^{-p})e^{-p} + x_3 (1 - e^{-p})e^{-p}$$

$$1 (x_2 + x_3) (1 - e^p) (1 - e^{-p})$$

$$x^3 = e^{3p} - e^p - 1 - e^p \quad (12)$$

Where as Ashcroft has proved to express same equation as (13) by substituting $x_2 = e$

Thus,

$$X^3 - 2X^2 + 1 = e^{1p} - e^{2p} + e^p - 2X^2 + 1$$

$$= e^{3p} - e^{2p} + e^p - 2e^p + 1$$

$$= (e^p - 1) (e^{2p} - 1) \quad (13)$$

On the similar lines

Case 3 :- i.e. for four machines

$$X^4 - 3X^3 + 3X^2 - 1 = (e^p - 1) (e^{2p} - 1) (e^{3p} - 1) \text{ ----- (14)}$$

Case 4 :- i.e. for five machines

$$X^5 - 4X^4 + 4X^3 - 3X^2 + 1 = (e^p - 1) (e^{2p} - 1) (e^{3p} - 1) (e^{4p} - 1)$$

and such on

3.7 THE ASHCROFT NUMBER :-

The Ashcroft number A_n is defined as the average number of effective (= running) machine hours per hour, when n machines are assigned to the supervision of one operator; in other words, the Ashcroft number is a measure of the expected output of the machines. The number A_n can be expressed in terms of X_n as follows :

The average number of consecutive operator tasks is X_n . If such task lasts λ hours, the operator is busy on the average $X_n \lambda$ hours at a time, during which some machines are nonproductive. Between these “chains” of tasks operator waits for a customer to demand service, and as long as he waits, all the machines are running. Suppose the number of times a machines stops (on the average) is m per machine hour. This would mean that the average length of a running period (between machine stoppage) would be $4/m$ hours. As there are n/machines (all assumed to be identical), each one stopping m times per machine hour, the average length of the interval in which all the machines are running would be $(1/m) n$, or $7/mn$ is the effective machine running time.

The ratio of service time to effective machine time was defined as p . But as a machine stops m times per machine running hour, and each stop would necessitate λ hours of immediate attention before it can again, therefore

$$p = \lambda m \quad (12-14)$$

If the average number of running machines is A_n , the production of service time per hour is $A_n P$. Therefore

$$A_n P = \frac{X_n \lambda}{X_n \lambda + (I/mn)}$$

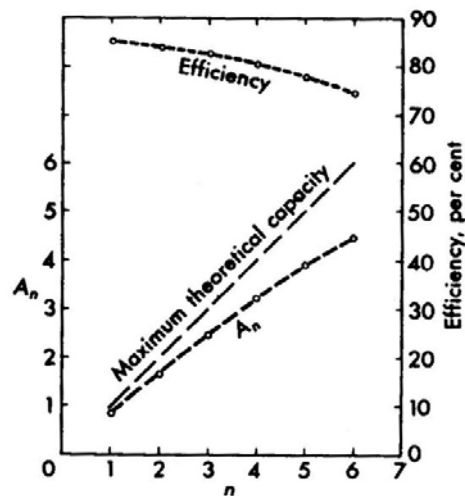
or

$$A_n = \frac{1}{p + (I/X_n \lambda)(I/mn)_p}$$

but since $p = m\lambda$,

$$A_n = \frac{1}{p + (1/nX_n)}$$

(12-15) and this is the formula on which the Ashroft tables are based, since X_n can be found for any given n and p . Values for A_n are shown in fig.



Examples showing the effect of machine interference on output and efficiency.

3.8 Examples

1. A Machine shop has to produce 100,000. Components for which the following times have been estimated.

Inserting place into machine	- 0.3 minutes
Starting the machine and engaging feed lever	- 0.1 minutes
Running time	- 3.25 minutes
Unloading components	- 0.2 minutes
Inspecting components	- 0.35 minutes

The following cost figures were provided by the accounting department.

Labour cost	- Rs. 4 per hour
Machine cost	- Rs. 5 per m/c hour
Over had & Material cost	- Rs. 3.2 per unit

- 1] Find the cost piece by using one operator with one, two or three machines.
- 2] Which combination will produce the pieces of 1,00,000 with minimum period.

(Amravati University)

(Summer 1987)

- 3] An order of 10,000 components have been produced by a Milling operation. Three identical milling machines are available in shop. The operation times and costs are as follows :

Inserting piece in machine	- 1.8 minutes
Starting machine	- 0.1 minutes
Machining time	- 2.5 minutes
Unloading time	- 0.6 minutes
Inspection	- 0.25 minutes
Walking between machines	- 0.05 minutes
Material cost	- Rs. 0.4 per piece
Labour cost	- Rs. 4 per hour
Overhead cost	- Rs. 6 per m/c hour

By utilizing one or two three machines by single operator:

- 1] Find out the cost per piece of manufacturing in each combination.
- 2] Which combination would you rule out?
- 3] Draw a man and multimachine activity chart for the best arrangement.

(Amravati University – Winter 87)

- 4] The problem of determining the number of identical machines to be assigned to one operator under deterministic conditions is as under:

A work cycle of a machine involve 'a' minute preparation time (loading and unloading) and 't' minute running time, since the machinestos automatically of the end of its task and requires no superision while running, the operator can superwise more than one machine. When there is complet matching of operator cycle time and machine cycle time the number of machines that the operator can look after is

$$n' = (a + t) / a$$

If n' is not a whole number, we have to select between (n) of (n + 1) machines, where $(n) < n'(n+1)$. Show that these are two alternatives, we need to consider because the figures (Amravati University)

(Summer – 1988)

5] A (i) Prove:-

$$A_n = \frac{1}{P + 1/nX_n}$$

Where X_n = Average no, of Consecutive servieing task for n machines where each task last for hrs. λ

$P = \lambda m$, where m are number of stops per hour per machines.

(ii) Show that when one machine is assigned to one operator, the column in the Ashcroft. Table for $n = 1$, is obtained by

$$A_1 = \frac{1}{1+P}$$

(iii) Show that when n fully automatic machines are supervised by one operator with random stoppages,

$$A_n = \left(\frac{N}{1+P} \right)$$

(Amravati University – Winter 1988)

3.9 EXERCISE :

- 1] What are the methods generally considered to reduce the cycle time to minimum?
- 2] Explain ‘Machine Output’
- 3] Elaborate various reasons behind reading the actual output compared to thereatical output.
- 4] What do you mean by ‘Machine Capacity’ which are those reasons involved in creating quantities decrepancy between theorotical and actual output ?
- 5] Which are the methods to reduce the cycle time in the multimachine supervision by one operator?
- 6] Explain machine interference during deterministic machine cycle.
- 7] Explain perfect matching in multimachine supervision.
- 8] Deduce :-

$$Y_n / Y_{n+1} = \frac{\varepsilon + n}{\varepsilon + n + 1} \times \frac{n'}{n} \quad \text{Where } \varepsilon = C_o/C_m = \text{Labour Cost} / m/c \text{ Cost}$$

$$n' = (a + t)a$$

a = No. of machines under a care of Operator.

Y_n = Cost per unit when n machines are chosen.

9] Deduce :

$$Y_n / Y_{n+1} = \frac{\epsilon + n}{\epsilon + n + 1} \times \frac{n'}{n} \quad \text{Where } n = \frac{a + t}{a + b}$$

b = the allowances for operators independent activity, minutes per machine.

$(a + t)$ = Machine work cycle.

$(a + b)$ = Operator's activity per machine.

10] Explain the purpose behind ASHCROFT tables which are those assumptions made while preparing table.

11] Prove ANCST, $X_2 - eP$, for the two machines under the supervision of one operator.

$$X_3 - 2X_2 + 1 = (eP + 1)(e2P - 1)$$

Where X_3, X_2 are ANCST, $P = at$

3] What is ASHCROFT No.?

4] Prove $A_n = \frac{1}{p + \frac{1}{n \times n}}$ where $X_n = \text{avg. no. of cost.}$

For n machines where each task for hrs. λ

$$p = n\lambda$$

15] Show that if an operator is re several machines with nonidentical cycle time, idle time inevitably occ

(Express this idle time quantity

16] Two identical machines with time

$T = (a_1 + t_1)$ and one machine

$2T = (a_2 + t_2)$ are assigned to that no perfect is possible.

17] An order to 1000 components have to be produced by a milling operation.

Three identical milling machines are available in the shop.

The operations times and costs are as follows.

Inserting piece in machine ---- 1.8 Minutes

Starting of machine ---- 0.1 Minutes

Machining time ---- 2.5 Minutes

Unloading ---- 0.6 Minutes

Inspection pieces ---- 0.25 Minutes

Walking between machine ---- 0.05 Minutes

Material cost ---- Rs. 0.4 per piece

Labour cost Rs 4 per hour

Overhead cost Rs 6 per m/c hour.

If a special milling fixture is used the inserting and unloading time can be reduced to 1 minute and 0.4 minutes, respectively, the cost of one fixture is Rs. 800/-.

(i) If only one operator is employed on this job, there are nine possible combinations of utilizing and one or two or three machines with or without fixtures. Find the costs per piece incurred by each of these combinations and hence the one involving the lowest cost pieces.

(ii) Which combinations would you rule out from the practical point of view?

(Note – if F=m/c with fixture

W=m/c without fixture

Following are the Nine possible

F FF FFF W WW WWW

FW FFW FWW

The above six combinations given identical cycles whereas next three combinations are with non-identical cycles.

18] A number of operators are performing the same task in a production centre, where the same machine is used by each in turn.

The task includes:

Cheak and set the components	-	0.65 minutes
Work with hand tools	-	0.32 minutes
Assembly	-	0.44 minutes
Walk to the machine	-	0.04 minutes
Operate the machine	-	0.3 minutes
Inspect before the next operations	-	0.1 minutes
Operate the machine again	-	0.15 minutes
Inspect the assembly	-	0.04 minutes
Walk back to the bench	-	0.04 minutes
Further operation by the hand tools	-	1.14 minutes
Find inspection and packing	-	0.46 minutes
Total cycle time	-	3.68 minutes
Cost of machine	-	Rs. 1.7 per hour
Cost of labour	-	Rs. 3.8 per hour

(i) How many operators should be engaged in this production centre?

(ii) Draw a multicitivity charts for the centre what maximum output would you expect to attain?

(iii) Find the production costs per piece for(i)

(iv) Would you expect operator's interference?Why?

(v) Would it be worthwhile allocating the final inspection and packing operation to one man? Compare the costs per piece for this case with the figure you obtained in 9ii).

(vi) Similarly, would it be worth allotting only the first task “Check and sit” to one operator?

(vii) Would you recommend combining plans (v) and (vi) what the costs analysis be in this case?

Note: If you find any errors please bring to our notice so that they can be corrected in next reprint.

5. Inventory control

ANALYTICAL STRUCTURE :

Inventory theory hardly requires the explanation because inventory immediately brings to our mind the stock of commodity. As per Fred Hanssman – An inventory is an idle resource of any kind, provided that such resource has Economic value. In business activity, we often observe the safety quantity requires in near future. Just like supermarkets are requested to cash pay cheques for their customer. Therefore, we can include currency notes as a tangible inventory. Similar analogous problems can be put forth like sales-girls requires during peak hours. It can be further noted that whether tangible inventory, is having virtually economic value.

Indirectly, inventory theory deals with the determination of the optimal level of such an resource. Therefore, planning in advance of the level of the resource is the subject of inventory theory.

Structure of inventory problems

There are two aspects –

1] procurement of commodity 2] its future demand

The inventory theory has been resulted into the difference among the practical inventory problems. These differences occur due to variation in the major structural components of the general inventory problems.

1] knowledge of demand 2] procurement process 3] decision process 4] probability distribution 5] time lag 6] relevant cost consideration

1) Knowledge of demand:

we require specific level of demand respect to time but the time when the decision of inventory reaches, we know least about the future demand, which can be categories in 3 ways on the basis of possibilities.

- 1] exact future demand
- 2] probability distribution of future demand on the basis of past demand.
- 3] entirely ignorant of the likelihood of future demand.

Above are designed as inventory problems under

- 1] certainty
- 2] risk
- 3] uncertainty

with reference to our knowledge of future demand.

2) Procurement process

There are two types of methods of obtaining the commodity. One is outside supply and second is self supply or self manufacturing item. There is always time-Lag between the placement of order and the receipt of the material. In some cases, the time lag is constant whereas, in other there is a probability distribution is a probability of possible time.

This distinction has fairly important consequences in the analysis of the inventory problems.

The inventory problems of self supplying commodity is more complex because they have to consider the effect of its ordering policies and complete process of production.

3) The Decision Process :

- 1) One shot decision
- 2) Repetitive Decision

The decision regarding the plant capacity fixation of new product, fashion goods purchases, storages of Dipawali Gifts, New year cards, Christmas tree, etc. are one shot decision and term as static inventory problems.

In other cases, repetitive decision are to be taken to replenish the material regularly, considering the time lag. Virtually, any inventory decision should be conceptualized as one in a series of similar decisions.

4) Probability Distribution of demand :-

In dynamic cases, constant level of demand is expected over a span time i.e. constant probability distribution. In state cases, the probability distribution varies with time.

5) Time – lag :-

There can be constant time lag or probability distribution of possible time lag in receiving the material.

e.g. Multiple warehouses with and without central ordering system.

e.g. Multiple item ordering to one supplier.

e.g. Cascades of inventories through raw material in process to finish goods inventories.

6) Relevant Costs or Costs in inventory :-

The various types of costs are involved and are to be measure in the analytical resolution of inventory problems

i) Procurement Cost

ii) Set up cost stockage cost

iii) Carrying cost or not carrying iv) Systemic costs

i) To determine and measure the relevant cost in the analytical resolution of inventory problems is procurement cost

A) For outside supply

B) For self supply

In case of (A) it can be ordering cost and (B) set up cost. The difficulty involved in the analysis of selecting the cost data can be formulated in two ways.

A (a) Common distinction between fixed cost & variable cost often lies in the work of procurement processed from the same building and same clerical staff used for executing the various orders and becomes difficult in deciding the exact ordering cost.

A (b) Another cost involved is cost or pay off and the opportunity – cost.

ii) B (a) Set up cost which should include complete hiring and firing, training and so forth the cost. The inventory decision problems in such cases are similar to production scheduling decision problems.

B (b) Stockage Cost is nothing but the cost of carrying and not carrying inventory.

CARRYING COST INCLUDES :-

i) The cost of the money tied up in the inventory – lost earning power cost. This depends on the use of money to which it would be put if it were available –

e.g. Investments to earn interest, e.g. Short term loan interest.

e.g. to retire company bond,

e.g. Government securities.

ii) Storage and handling cost – Space rent, lighting, heating and air – conditioning or on the other hand (space) fixed cost if the space cannot be utilized elsewhere.

iii) Deterioration Cost – Which includes loss and deterioration pilferage, breakage and also varies damage of commodity.

iv) Insurance Cost

v) Overstock cost for the stock left on hand after the demand is fulfilled.

vi) Store staffing, equipment maintenance and running cost is involved.

NOT CARRYING COST OR OUT OF STOCK COST :-

There are two variants of this cost depending on the reaction of the prospective customer to the out of stock situation.

In first case – Mail order sales where after receipt of order expedite to replenish the goods. This situation is called back order resulting into additional cost of expediting, special handling packaging and shipping.

IN SECOND CASE –

- i) When the order is lost
- ii) Loss of good will
- iii) Less likely to return to that outlet to other purchases causing loss of future sales

iv) Systemic Cost –

The Dynamic inventory cases depends on systemic factors like potential saving due to data processing. This requires to amalgamation of orders for several items into one order.

THE STRUCTURE OF THE ANALYSIS

Every inventory problems are connected with cost and indirectly, cost is opposing the inventory.

∴ Inventory \propto cost

Cost is associated with doing ‘too much’ or ‘too little’. This statement is value because question remains with ‘too much’ or ‘too little’ of what ?

Now while resolution of any inventory problems requires the Answer to Questions when and How much i.e. Quantity of ordering and the frequency of ordering. Which will be the optimal policy and depends upon the state of knowledge of future demand. Naturally, total cost depends upon all of the relevant opposing costs. The possible course of action which minimises the expected total cost and the aim is to analyse and then decide absolutely best course of action.

THE OBJECTIVES OF CARRYING INVENTORY

It is assumed that costs and or profits are the satisfactory measure of pay-off for the analysis of company’s objective could be measured in terms of Rs. but many decision problems can be formulated quantitatively.

Rs. are not satisfactory measure where

- 1) When decision is not simply base on profit when maximum share is to achieved.
- 2) The utility of money is the objective where the resources are at risk.

The following are the main reason for holding stocks –

- i) To ensure the availability of sufficient goods to meet anticipated demand.
- ii) To absorb variations in Demand and production.
- iii) To provide a buffer between production processes.
- iv) To obtain discount on bulk purchases.
- v) To meet possible shortages in future.
- vi) To absorb seasonal fluctuation in usage of demand.
- vii) To retain the smooth production process.
- viii) To necessary part of process e.g. molasses.

The major purposes of inventories, they serve can be classified in three kinds as suggestion by Keynes for holding stock of cash.

- 1) Transaction
- 2) Precautionary
- 3) Speculative

TRANSACTION :-

Motive results even in case certainly too difficult to match perfectly the inflow and outflow. Inventories are held to match the state due to lack of synchronization.

Precautionary Motive result for a kind of safety under the market of risk. Secondly instantaneous delivey at the same cost.

STATIC INVENTORY PROBLEMS UNDER RISK :

In such cases, the most considerations are offered for the inventory problems, when probability distribution of demand is involved. As we know that m it is difficult to determine the level of probability distribution, from the previous data.

CHARACTERISTICS :-

- 1) The distinguishing feature is that only one procurement order is possible.
- 2) The salvage value or overstock cost arises.
- 3) The ordering cost is a fixed for all courses of action, hence neglected.

AN ANALYTICAL APPROACH

Construct a pay off matrix for an inventory decision problems of Christmas tree for sale by a small merchant during a season. The probability distribution of demand as under is known to merchant. The meaning of 0.05 probability demand of one tree means the if the same situation were repeated for a great many reasons we could expect that in 5% of the seasons there would have been demand for only one tree.

Demand Reasonable – Courses of action, Strategies	Probability
1	0.05
2	0.15
3	0.2
4	0.4
5	0.1
6	0.1
	----- 1.00 (unity) Becomes one of the probability must occur

Say, Cost of tree is Rs.2 Ordering cost
Selling price Rs.6 Carrying cost % ignore
Delivery Charges Rs.0.5 Loss of Goodwill
Salvage cost Rs.0.5

Determine the optimal number of trees, the merchant to order, if he cannot, sale more than six and no possibility of ordering less than one.

The whole essence, of this kind of problems is that we do not know what level of demand will, in fact, occur.

PAY OF MATRIX

Demand Z	1	2	3	4	5	6	Expected Ev. Value
P Order, x	0.05	0.15	.2	.4	.1	.1	
1	3.5	3.5	3.5	3.5	3.5	3.5	3.5
2	2	7	7	7	7	7	6.75

3	0.5	5.5	10.5	10.5	10.5	10.5	9.25
4	-1	4	9	14	14	14	10.75
5	-2.5	2.5	7.5	12.5	17.5	17.5	10.25
6	-4	1	6	11	16	21	9.25

Expected value of pay off for each strategy can be computed by taking a multiplication of p and condition profit or loss value for that combination of demand and strategy and summation of all such multiplication e.g.

$$\text{III Strategy, } E_v = 0.05(0.5) + 0.15(5.5) + 0.2(10.5) + 0.4(10.5) + 0.1(10.5) + 0.1(10.5) \\ = 9.25$$

The expected value of an event is its probability times the outcome or value of the Event over a serious of Trials.

Now, if the same type inventory decision problems repeated, the advice go for 4 tree instend of 5. But always it is not possible, Because

- 1) Different type of series of problems each time
- 2) Merchant may go for bankrupt, desirous to harness maximum profit.

THE OPPORTUNITY COST MATRIX

Let up considered the profit, that would have been made, if there had been more stock available. If the strategy else other than selected and fortunately the actual demand would have occurred, resulting into more profit. In other words, the opportunity had lost.

e.g. the event F61 = - 4 (Conditional loss)

But eventuate F 11 = 3.5 (Conditional profit)

∴ True cost of our decision to stock six trees, which is opportunity cost for

$$F 61 = 3.5 - (-4) = 7.5 = \text{loss actually sustained}$$

Suppose, F 61 = 3.5 (Profit)

$$F 66 = 21$$

True Cost = 21 - 3.5 = 17.5 profit would have been stock six trees.

Opportunity cost of best decision for the given level of demand is zero.

Opportunity cost is the cost sustained because the decision taken was not best in terms of the demand of level eventuates.

Therefore, we can construct the opportunity cost matrix as under & compute the expected opportunity cost, for each strategy.

OPPORTUNITY COST MATRIX

Demand/z	1	2	3	4	5	6	Expected
----------	---	---	---	---	---	---	----------

							O C
Order X P	0.05	0.15	0.2	0.4	0.1	0.1	
1	0	3.5	7	10.5	14	17.5	9.275
2	1.5	0	3.5	7	10.5	14	6.025
3	3	1.5	0	3.5	7	10.5	3.525
4	4.5	3	1.5	0	3.5	7	2.025
5	6	4.5	3	1.5	0	3.5	2.525
6	7.5	6	4.5	3	1.5	0	3.525

1. O indicates the best decision

2. Where order quantity $x < z$, opportunity cost of Rs.3.5 for each tree sustained

3. Where $x < z$, cost of Rs. 1.5 for each tree sustained

There, minimum opportunity cost will be the best decision, and proved that the means of opportunity cost will always exactly the same conclusion that of the analysis given by pay off matrix

Expected O.C, for the strategy

$$\begin{aligned}
 &= 0.05(3.5-3.5)+0.15(7-3.5)+(10-3.5)+.4(14-3.5)+0.1(17.5-3.5)+0.1(21-3.5) \\
 &= 9.275 \\
 &= \{0.05(3.5)+0.15(7)+0.2(10.5)+0.4(14)+0.1(17.5)+0.1(21)\} \\
 &= \{0.05(3.5)+0.15(3.5)+0.15(3.5)+0.2(3.5)+0.4(3.5)+0.1(3.5)+0.1(3.5)\} \\
 &= 12.775 - 3.5 = 9.275
 \end{aligned}$$

i.e. EOC for a given strategy

$$= 12.775 - \text{Expected pay off (EF),}$$

For any pay off matrix, in term of profit

$$\text{EOC} = K - \text{EF, where } K = \text{Constant}$$

Or For any pay of matrix, in terms of loss,

$$\text{EOC} = \text{EF} - K$$

This analysis reveals –

1. Original Pay off matrix does take account of lost potential profit, but in some what disguised form.
2. There are two opposing cost involved in Eoc matrix
3. The opposing cost is evident, for overstock and understock, Rs 1.5 and Rs 3.5
4. These cost are opposing each other. There is less risk in stocking more trees for sustaining cost but greater risk of sustaining overstock cost.

5. Above facts is not obvious in the analysis for pay off matrix but is high lighted by O.C.matrix.

INCREMENTAL ANALYSIS

The explicit presentation of two opposing costs in the form of O.C. permit to analyse this kind of problem, in much simple way by incremental analysis.

If the merchant makes series of decision like

Ordering 1 tree – not to order 1 tree

$$2 \quad - \quad 2$$

Until he decides not to order next tree

To analyse – say $P (Z = 3) = 0.2$ i.e. Probability of demand equal to 0.2

When Z equals to three.

Similarly $P (Z > 3) = 0.8P (Z < 3) = 0.2$

Suppose merchant reaches the i^{th} decision that whether to order i^{th} tree or not. There are two probabilities, either there will be demand for i^{th} tree or will not be.

The decision problem (Inventory) can be displaced in 2x2 O.C.matrix.

	Demand for i^{th}	No demand for i^{th}
Order i^{th} tree	Rs 0	Rs 1.5
Don't order i^{th}	Rs 3.5	Rs 0

Thus EOS, for

Order i^{th} tree, $(0) P (z \geq i) + 1.5 [1 - p(z \geq i)]$

$= 1.5 - 1.5 p (z \geq i)$

Don't order, $(3.5) p (z \geq i) + = [1 - p(z \geq i)]$

$= 3.5 p (z \geq i)$

That quantity will be ordered out where EOC for ordering will be less than for ordering.

The order for i^{th} will be executed if an only if

$1.5 - 1.5 p (z \geq i) < 3.5 p (z \geq i)$

or $1.5 < 5 p (z \geq i)$

or $0.3 < p (z \geq i)$

The probability is greater than 0.3. This can be immediately decided from the probability distribution of demand.

Like

Demand	$p(z = i)$	$P(z \geq i)$
1	0.05	1
2	0.15	0.95
3	0.2	0.8
4	0.4	0.6
5	0.1	0.2
6	0.1	0.1

$$P(z \geq 4) = 0.6 \geq \text{But}$$

$$P(z \geq 5) = 0.2 \geq 0.3$$

Hence 4th strategy would be ordered and not 5th strategy.

COMPARISION :-

1. We can equally well analysis, the given inventory problem either in terms of a pay of matrix or else in terms of cost matrix.
2. Analysis are equivalent and produce the same choice of a strategy.
3. Both analysis may mix together and will confuse because some entries will be in to of total profit & cost and other entries in terms of opportunity costs.
4. Exactly same conclusion with less arithmetic
5. It is quite clear, that the opposing costs and their relation help to analysis the problem

The cost of Risk :-

$$EOC = K - EF, \text{ What is K ?}$$

It is calculated by the largest entries in each column.

It is expected value of the pay off during best course of action.

This can be elaborated precisely as follows suppose, we are omniscient regarding the inventory problem under consideration, then we know what exact level of demand will occur and select the strategy accordingly.

Suppose, we are omnipotent, we can control the level of demand and arrange the thing so that there would be demand for six trees. We will always stock 6 trees & will make a profit of Rs.21, always.

But, since being omniscient, gives us no control but we will select the best strategy resulting into

$$\begin{aligned} EF &= 0.05 (3.5) + 0.15 (7) + 0.2 (10.5) + 0.4 (14) + .1 (17.5) + 1 (21) \\ &= 12.775 \end{aligned}$$

K is the average amount we would made if we had a perfect information

Now, Largest expected profit is Rs 10.75 for the 4th strategy, whereas expected profit is Rs 12.775, could be made. The difference between two values is Rs 2.025 and is called Eoc for the strategy of ordering four trees. This suggest that Eoc of optimal strategy is the upper limit and Eoc generates the cost due to lack of perfect information of decision maker. Perfect knowledge can be obtained, by suitable, market survey, market research of any other method to evaluate the potential demand.

OTHER COST STRUCTURES :-

The similar analysis can be extended for the other cost like carrying cost, Cc, or loss day to loss of Goodwill etc. Consider the manufacturer, purchasing one machine tool and having problem of purchasing a space of Rs 100 each, because supplier is closing down business.

During the breakdown, due to spare, which cost Rs.1000 to manufacture including downtime cost. If the life time of machine is 10 years and the probability distribution of number of failures due to spare as under presuming salvage cost to zero & Neglect, Cc.

Failure	0	1	2	3
P	3	4	2	1

Here the main difference in Christmas tree inventory problem and this problem is that here we are reasoning in terms of costs which should be as minimum as possible against the maximising profits. In such cases O. C. matrix should be prepared only after construction a matrix; as under

COST MATRIX

Order/Demand	0	1	2	3
0	0	1000	2000	3000
1	100	100	1100	2100
2	200	200	200	1200
3	300	300	300	300

O. C. MATRIX

Order/Demand	0	1	2	3
0	0	1000	2000	3000

1	100	100	1100	2100
2	200	200	200	1200
3	300	300	300	300

O.C. MATRIX

0	0	900	1800	2700
1	100	0	900	1800
2	200	100	0	900
3	100	200	100	0

THE MATHEMATICAL FORMULATION – THE DISCRETE CASE

There are different kinds of inventory problem with great many possible level of demand which cannot be explicitly presented in the pay off matrix. Therefore, pay off matrix will be convenient by using incremental analysis. Further some problems do not hold stock units like liquids which are basically continuous as compared to the discrete kinds of problem discussed earlier. For these reasons, it is desirable to have a general formulation of this know of inventory problems where some mathematical notation will be introduced, keeping the logic of analysis same as earlier.

Let us presume that carrying cost is absent. Then the two opposing cost are Rs 100 stocking and Rs 1000 for understock.

C = Total cost of one unit.

C_u = Total cost of an under stock/unit

p(z ≥ j) = probability, when demand z – j

$$p(z \geq j) = \sum_{i=j}^N p_i = \sum_{i=j+1}^N p_i$$

$$p(z \geq j) = \sum_{i=j}^N p_i = \sum_{i=0}^{1-j-1} p_i \quad \text{Where } N = \text{Largest possible demand}$$

i = Dummy of summation

EF_k = Expected pay off for the k th strategy

$$EF_k = (F_{k_n}) P_n + 1 (F_{k_1}) P_1 + \dots + 1 (F_{k_n}) P_N$$

$$OR\ EF_k = \sum_{i=0}^N F_{ki} P_i \text{ ----- (1)}$$

This takes two forms, depending on whether the amount ordered k, was less than on greater than the demand level j.

We have

$$F_{k1} = \begin{cases} Ke & \text{if } k = j \\ Ke + (i - k) Cu & \text{if } k < j \end{cases}$$

Substituting these expression in (1)

$$EF_k = \sum_{i=0}^N Ke + \sum_{i=k+1}^N [Ke + (i - k) Cu] P_i$$

$$= \sum_{i=0}^N Ke + \sum_{i=k+1}^N P_i + Ke \sum_{i=k+1}^N P_i - Cu \sum_{i=k+1}^N i P_i$$

or $EF_k = Cu + \sum_{i=k+1}^N i P_i - K Cu \sum_{i=k+1}^N P_i$

This find out the specific strategy, which has the smallest expected total cost. If K strategy has the smallest expected value, in particular, the two adjoining strategies (K+1) and (K-1) have large total costs. Therefore expected total cost for these two strategies are

$$EF_{k+1} = (k + 1) C + Cu \sum_{i=k}^N i P_i - Cu \sum_{i=k+2}^N P_i$$

$$And\ EF_{k+1} = (k - 1) C + Cu \sum_{i=k}^N i P_i - Cu \sum_{i=k}^N P_i$$

These two expected total costs, in terms of the expected total cost of k, will be

$$EF_{k+1} = EF_k + c - Cu \sum_{i=k+1}^N P_i$$

$$\text{And } EF_{k-i} = EF_k - c + Cu \sum_{i=k}^N P_i$$

Thus, above relationship indicates that any strategy of ordering more than $k + 1$ or less than $k - 1$ will produce still larger expected total cost. Because in case of $K + 2$, +ve terms remains fixed and -ve terms gets smaller. Similarly in case of $K-2$, -ve terms remains fixed and +ve terms gets larger. We have to find the K strategy; which is true if following holds good.

$$EF_{k+1} - EF_k = C - Cu \sum_{i=k+1}^N P_i = 0$$

$$\text{Or } \sum_{i=k+1}^N P_i > \frac{C}{Cu}$$

$$EF_{k-1} - EF_k = -C + Cu \sum_{i=k}^N P_i > 0$$

$$\text{Or } \sum_{i=k}^N P_i > \frac{C}{Cu}$$

This is simultaneously true if and

$$\text{Only if } \sum_{i=k}^N P_i > \frac{C}{Cu} > \sum_{i=k+1}^N P_i$$

This is equivalent to

$$P(Z \geq k) > \frac{C}{Cu} > P(Z \geq k + 1) \text{ ----- (2)}$$

In order to use this relationship, the probability of the form $P(Z \geq k)$ is to be known to be Break even probability

$$\text{e.g. } C / c_u = \frac{100}{1000} = 0.1$$

Demand K.	P (Z = E)	P (Z = K)
0	0.3	1.0
1	0.4	0.7
2	0.2	0.3
3	0.1	0.1

In equation (2), the relationship is expressed in terms of inequalities but in this case, relationship holds with equality because of the two strategies having same expected total cost.

$$P(Z \geq 2) > 0.1 = P(Z \geq 3)$$

$$P(Z \geq 3) = 0.1 > P(Z \geq 4)$$

This concludes that the order for either 2 or 3 spare can be placed. Verify that in both the strategies expected total cost is Rs. 300. Even by applying incremental O.C. analysis, on the spare part problem, it shows that the last strategy for which $P(Z \geq j)$ should be selected.

$$\text{Equation (2) can be represented by } P(Z \leq k) < \frac{C_u}{C + C_u} < P(Z \leq K + 1)$$

Then

K	P (Z = K)	P (Z ≤ K)
0	0.3	0.3
1	0.2	0.7
2	0.2	0.7
3	0.1	1.0

$$\text{Then } \frac{C_u}{C + C_u} = \frac{1000}{100 + 1000} = \frac{10}{11} = 0.9$$

∴ Either 2 or 3 spare can be purchased.

CHARACTERISTICS :-

1. This analysis and incremental analysis gives the considerable degree of similarities in their conclusion.
2. This analysis is based on the total cost consideration whereas incremental analysis was on O.C. basis.

3. Comparison can be done, since, first analysis is based on total cost matrix and second on profit matrix.
4. Equality and inequality for incremental analysis has the same effect as with this analysis.
5. Both yields the same result.

GENERAL COMMENTS :-

It is unlikely and all the time similar kind of inventory problems will occur. But when such problem occur, the solution can be easily found out by analytical approach provide relevant information is in hand.

The major problem is how to obtain the information concerning the probability distribution of demand ? The time & cost of a study to determine the demand distribution can often exceed far, for complex inventory analysis. But when the demand distribution is not know. We are no longer dealing with an inventory problem under risk, but with one under uncertain.

Ex.1 A flower store in a small community must stock some orchids (a kind of flower) to be sold as corsages for the high school prom. On the basis of past demand, the store own estimates the probability distribution of demand to be

Demand	6	1	2	3	4	5
Probability	.05	.1	.25	.35	.15	.1

Only one order can be placed. The orchids cost the store owner Rs 5 each and lie sells for Rs 12.5 each. Delivery of a corsage cost Rs 0.5 for each one. Any orchids unsold after prom are a total loss (i) Construct the pay off matrix and find out optimal order size ? Construct O.C.matrix (iii) Use O.C.and incremental analysis to verify the solution. What is maximum possible worth of additional information to the store owner.

What salvage value would justify an optimal strategy of ordering one more orchid than found (i) ?

SOLUTION :

PAY OFF MATRIX

Z	0	1	2	3	4	5	EF
x p	0.5	1	.25	.35	.15	.1	
0	0	0	0	0	0	0	0
1	-5	7	7	7	7	7	6.4
2	-10	2	14.5	14.5	14.5	14.5	12.025
3	-15	-3	9.5	22	22	22	14.525

4	-20	-8	4.5	17	29.5	29.5	12.65
5	-25	-13	-5	12	24.5	37	12

For $x \geq Z$, Pay off = $-5 x + 12.5 Z - 0.5$

$x < Z$, = $7.5 x - 0.5$

Max EF = 14.525, which is for 4th strategy i.e. 3 number of orchids should be ordered out

(v) 4 orchid, pay off is 12, loosing $(22-17) = 5$, which should recover from salvage.

O.C. MATRIX

Z	0	1	2	3	4	5	Expected
X p	0.5	0.1	0.25	.35	.45	.1	20.15
0	0	7	14.5	22	29.5	37	20.15
1	5	0	7.5	15	22.5	29.5	.13.7
2	10	5	0	7.5	15	22.5	8.125
3	15	10	5	0	7.5	15	4.725
4	20	15	10	5	0	7.5	7.5
5	25	20	15	10	5	0	.9.45

Max O.C is 4.725 for the 4th strategy. Thus 3 orchids should be ordered out.

INCREMENTAL ANALYSIS

	Demand i th	No demand i th
Order i th	0	5
Not to Order i th	7.5	0

Order ith EOC, $(O) P (Z \geq i) + 5 [1 - p (Z \geq i)]$

= $5 - 5 P (Z \geq i)$

Not order ith, $(7.5) P (Z \geq i) + O [1-p(Z \geq i)]$

$7.5 p (Z \geq i)$

\therefore EOC for ordering < EOC for Not ordering

$5 - 5 P (Z \geq i) < 7.5 p (Z \geq i)$

$$5 < 12.5 P(Z \geq i)$$

$$0.4 < P(Z \geq i)$$

Demand	P (z = i)	P (z ≥ i)
0	.05	1
1	.1	.95
2	.25	.85
3	.35	.6
4	.15	.25
5	.1	.1

$$\text{Hence } P(Z \geq 3) = 0.6 > 0.30$$

$$P(Z \geq 4) = 0.25 < 0.30$$

There, 3, orchids should be ordered out.

EX.2

(a) A company is making a large boiler installation. A certain automatic monitoring unit is crucial for the operation of the whole system. At the time of the original order spares for this unit can be purchased for Rs 2000 each. The probability distribution for failures of this unit during life time of the installation is known to be

Demand	0	1	2	3	4
p	.35	.25	.2	.15	.05

If the spare is needed and is not available the total cost to the company in down time and replacement cost will be Rs.15000. Unused spare have no salvage value. What is the total cost matrix and the optimal number of spares to be order? (b) what O.C.matrix (c) What is maximum possible with of additional information (d) What is the mathematical equation which describes this problem ?

$$\text{Solution } C = \text{Rs } 2000/- \quad C_e = 0$$

$$C_u = \text{Rs } 15,000/- \quad \text{Salvage cost} = 0$$

Cost Matrix (Rs. '000)

P	35	25	.2	.15	.05	Expected
1	0	1	2	3	4	OC ---
0	0	15	30	45	60	19.5
1	2	2	17	32	47	9.49
2	4	4	4	19	34	7.75
3	6	6	6	6	21	6.75

4	8	8	8	8	8	8
---	---	---	---	---	---	---

O.C. Matrix (Rs '000)

	0	1	2	3	4
0	0	13	26	39	52
1	2	0	13	26	49
2	4	2	0	13	26
3	6	4	2	0	13
4	8	6	4	2	0

$$(d) \quad p(z \geq k) > C/C_u > p(z \geq + 1)$$

$$> \frac{2}{15}$$

$$> 0.133$$

Demand	P (z = k)	P (z ≥ k)
0	0.35	1.0
1	0.25	0.65
2	0.2	0.4
3	0.15	0.2
4	0.5	0.05

STATIC INVENTORY PROBLEMS UNDER UNCERTAINTY

There are few cases where we are unknown about the probability distribution but at the same time, we are not fully ignorant about it. Such intermediate cases, presuming some information, are treated under UNCERTAINTY for discussion. We are reserving some risk for the case with complete knowledge of probability distribution. Thus 'Uncertainty' mean to put partial, knowledge under risk and leave uncertainty for the case of total ignorance.

GENERAL CHARACTERISTICS

1. Only one order is to be executed
2. Probability of distribution of demand is unknown
3. The frequency and kind of problems are similar to static – risk cases
4. Cost consideration are equally same as in static – risk cases.

DECISION CRITERIA UNDER UNCERTAINTY

The probability distribution is unknown. We can construct the pay off matrix and in few cases the expected pay off which becomes the basis for decision. The various criterias are suggested by different authors and becomes the alternative rules. Each criteria suggested are supported by arguments asserting its plausibility (seemingly acceptable) and superiority over the other. Naturally, the criteria adopted for variety of problem is to be analysed before taking a decision.

There are major 3 – different criteria

1. By Abraham Wald

Maximin criteria	-	Pay off matrix
Minimax criteria	-	Cost matrix

So select the maximum such minimum (Best of the worst) pay off strategy. In case of cost matrix select a strategy yielding minimum amongst maximum pay off from above maximum (Best of the Best) alternatives rule is evolved which is an optimistic the decision maker. The idea of Abraham Wald is to act at most conservation, assume worst possible thing is going to happen to us and thus safeguard by selecting and which makes this worst thing as good as possible.

2. By Leonard Savage

He suggested regret theory and based on minimax regret. The alternative rule seeks minimise the maximum regret that there would be from selecting a particular strategy. The decision maker always regret himself that he could not select the best course of action otherwise maximum profit would have achieved. Thus the degree of regret always tries to reduce by specific pay off resulting from his selection. Regret matrix is nothing out the opportunity matrix which is governed by decision maker as a desire to minimise this regret which ultimately he will experience.

Say for example

O.C.MATRIX FOR

Strategy	1	0	3.5	7
	2	1	0	3.5
	3	3	1.5	0

For applying minimax criteria on above regret, we have maximum regret.

Strategy	1	7
	2	3.5
	3	3

So select minimum such maximum regret i.e. strategy I will selected.

3. By Thomas Bayes and P.S. Laplace There is acrimonious (Bitterness of language) debate from so many years on this theory, since, we are ignorant about probability of all levels of demand, author is recommending, equal probability occurrence and proceed to solve problem as earlier done in static risk cases. In this theory, idea is to convert uncertainly risk.

ARGUMENTS :-

1. Abraham wald theory select the lowest level of demand from pay off, where as from O.C. matrix, if applied will be resulting highest level of demand.
2. Leanard J. Savage theory is good in practice because it is based on criteria of opportunity. It suggest never to analyse pay off but O.C. will give decision on selection.
3. Thomas & Laplace theory pays equal weights to all strategy. However it will never end up with selection of strategy.

Ex. The following table shows the potential profits and losses which are expected to arise from launchings various products.

	Boom	Steday state	Recession
Product A	+ 8	1	-10
B	- 2	+6	12
C	+ 16	0	- 26
Probability	0.6	0.3	0.1

Apply the Maximin, Maximax,
Minimax and Minimax Regret alternative rules

SOLUTION :-

$$\begin{aligned}
 \text{EV A : } & 0.6 \times 8 + .3 \times 1 - 10 \times 0.1 & = & 4.1 \\
 \text{EV B : } & -2 \times 0.6 + .3 \times 6 + 12 \times 0.1 & & 1.8 \\
 \text{EV C : } & 0.6 \times 16 + (0.1 \times -26) & = & 7
 \end{aligned}$$

As per EV rule the ranking would be

C A B

The cautions Rule – Maximin, the worst losses are

A - 10

B - 2

C - 26 Ranking **B A C**

The optimistic Rule – Maximax, the Maximum gains are

A + 8

B + 12

C + 16 Ranking **C B A**

Minimax – It is applicable to cost matrix

Minimax Regret decision rule seeks to “ Minimize the max regret” by choosing a particular strategy the O.C. table from taking one decision given that a certain contingency occurs –

Regret Table in Rs. 000^s

	Boom	Steady	Recession
A	8	5	22
B	18	0	0
C	0	6	38

The O.C. are calculated by setting the best position under any to zero and then calculation the amount of shortfall there is by not being at that position

A 22

B 18

C 38 Ranking **B A C**

Ex United Cars Ltd is considering issuing 100,000 shares to raise capital needed for expansion. It is estimated that if the issue were made now, it would be fully taken up at a price of Rs 30 per share.

However, the company is facing two crucial situations, both of which may influence the share price in near future, namely –

(a) A wage dispute with tool room operator which could lead to a stick and have an adverse effect on the share price.

(b) The possibility of a substantial contract with a large company overseas which would increase the share price.

The four possible outcomes and their expected effect on the share price are

E1 = No strike & Contract obtained = Rs 34

E2	=	Strike & contract obtained	=	Rs 32
E3	=	No strike & Contract lost	=	Rs 32
E4	=	Strike & contract lost	=	Rs 16

Management has identified three possible strategies that company could adopt.

S1	=	Issue 100,00 shares
S2	=	Issue 100,000 Shares only after the outcomes of (a) & (b) are known.
S3	=	Issue 50,000 Shares now and 50,000 Shares after the outcome of (a) and (b) are known.

(i) Draw up a pay off table for the company and determine the minimax regret solution. What alternative Criteria might be used ?

(ii) It has been estimated that the probability of a strike is 55% and 65% of chance of getting the contract, these probabilities being independent. Determine the optimum policy for the company using the criteria of maximising expected pay off.

(iii) Determine the EV of perfect information for the company and indicate how the maximum expected pay off, the EV of perfect information and minimum expected opportunity and minimum re-expected opportunity loss are related what use can the company make of these values ?

SOLUTION :-

Pay off Table (Rs.'000')

OUTCOMES

Strategy	E1	E2	E3	E4
S1	30	30	30	30
S2	34	30	32	16
S3	32	30	31	23

S3 row is obtained by

E1	E2	E3	E4
$50 \times 30 + 50 \times 34$		$50 \times 30 + 50 \times 32$	$50 \times 30 + 50 \times 10$
= 32	30	31	= 23

From the pay off table, the regret can be obtained.

	E1	E2	E3	E4	Max Regret
S1	4	0	2	0	4
S2	0	0	0	14	14

S3	2	0	1	7	7
----	---	---	---	---	---

Minimax Regret solution is S1 i.e.4

Alternative includes

Maximum i.e. strategy with highest minimum pay off, S1 = 30

Maximax i.e. highest pay off strategy, S2 = 34

(ii) Maximising expected pay off Probabilities of outcomes are not given directly but can be easily calculated

$$E1 = .45 \times .65 = 0.2925$$

$$E2 = .55 \times .65 = 0.3575$$

$$E3 = .45 \times .35 = 0.1575$$

$$E4 = .55 \times .35 = 0.1925$$

EXPECTED PAY OFFS

	E1	E2	E3	E4	E5
	2925	.3575	.1575	.1925	
S1	30	40	30	30	30
S2	34	30	32	16	28.79

Therefore, S1 has highest pay off i.e. Rs 30 lacks.

(iii) The EV of the (highest) perfect information is the difference between the expected pay off of Rs.3 x 10⁶ and the amount which would be achieved if outcomes were known in advance. Thus

	Max Pay	Probability	Expected pay off with perfect information
E1	34	.2925	9.94
E2	30	.3578	10.72
E3	32	1576	5.04
E4	30	.1925	5.78

			31.48

--	--	--	-------

Expected Value of perfect information EV

= Rs 3.148 m – 3m

= Rs 148000

Ex. The Alpha Toys Ltd. is proposing to introduce to the market a radio controlled toy. It has three different possible models x y z which vary in complexity but it has sufficient capacity to manufacture only one model. An analysis of the probable acceptance of the models has been carried out and resulting profit are estimated.

Model Acceptance	Amount	Profits (Rs 000)		
		Model Type		
		x	y	z
Excellent	3	120	100	60
Moderate	5	80	60	50
Poor	2	30	-20	0

(i) Determine the model type which maximises the expected profit. What is the expected profit?

(ii) Obtain an opportunity loss table as show that the difference between expected opportunity losses is the same as the difference/between expected profits.

(iii) How much would it be worth to know the model acceptance level before making to decision on which model type of produce.

(iv) Further market research trend to confirm the probability of 0.3 for the 'Excellent' Model acceptance. However, the probabilities for moderate and poor are uncertain. But letting P be the probability of a moderate model acceptance, determine the expected profits for each model type as function of P. Hence, determine the range of value P for which model x is to be preferred.

SOLUTION :-

(i) **Pay off Table (Rs.'000)**

Acceptance	P	Model		
		X	Y	Z
Excellent	0.3	120	100	60

Moderate	0.5	80	60	50
Poor	0.2	-30	-20	0
Expected Profit		70	56	43

For Maximum choose Model X

Opportunity Loss Table

	P	X	Y	Z
E	3	0	20	60
M	.5	0	20	30
P	0.2	30	20	0
EOL		6	20	33

FOR MINIMUM CHOOSE MODEL X

Difference	X Y	X Z	Y Z
Expected profit	14	27	13
EOL	14	27	13

(iii) If there is certain knowledge of the acceptance level the opportunity loss is zero as EOL is Rs 6000 the value of having perfect information is Rs 6000 – 0

Rs 6000

(iv) This part of the question involves the use of sensitivity analysis i.e. discovering the range of values for which x is to be preferred.

$$P \quad (E) \quad = \quad 0.3$$

$$P \quad (M) \quad = \quad P$$

$$P \quad (P) \quad = \quad 0.7 - P$$

Expected profit for x, using profits from pay off table is

$$X \quad = \quad (120 \times .3) + 80P - 30(0.7 - P) \quad = \quad 15 + 110 P$$

$$Y \quad = \quad (100 \times .3) + 60P - 20(7 - P) \quad = \quad 16 + 80 P$$

$$Z \quad = \quad (60 \times 3) + 50P \quad = \quad 18 + 50 P$$

By Substituting of various values of P, in the three equations it would be found from

When

P is < 0.05 , Z gives Max Profit

P $> 0.05 \leq 0.7$, X give Max profit.

P $= 0.05$ X and Z give Max Profit.

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- **PRODUCTION PLANNING AND CONTROL (P.P.C) RS 50/-**
- **MACHINE TOOL CONTROL**
- **PROCESS ENGINEERING**

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6. DYNAMIC MODELS

DYNAMIC MODELS UNDER CERTAINLY :

Dynamic models under certainly are ones which deals with dynamic inventory problem where the level of demand of constant rate or variable rate over a period of time is taken.

CHARACTERISTIC :-

1. More than one order is possible
2. No need to consider possible distribution of overstock or under stock demand.
3. The cost of understock or overstock will be absent.
4. Ordering cost for multiple orders is to be introduced to reflect the penalties for mere orders.
5. There is a carrying cost, C_c to penalise the maintenance of higher average level of stock.
6. The analysis will be based on balancing the order cost, C_o v/s carrying cost C_c .

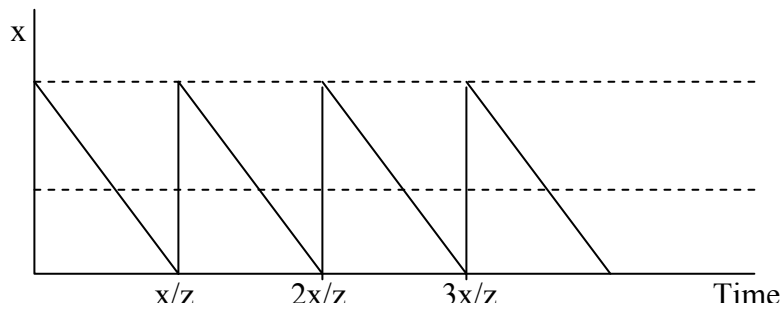
OPTIMAL LOT-SIZE, MODEL WITH COSTANT DEMAND :-

This is supposed to be the most oldest and widely used inventory model. The reason is that same derivation are giving the result in production planning for the determination of batch Quantity. Also, due to its simplicity, industrial engineers developed this particular analysis.

The analysis is based on the assumption that there is a constant demand over known time. If the items, in question, are manufactured oversalves, the cost of order placement is

called set up cost and if the items are purchase from subcontractors or outside parties, it will be denoted be order cost (Cr.) The carrying cost (Cc) is denoted by % of tied up money in inventory, for a period of time.

Suppose, we require to order Z items for a period of time. The frequency of ordering can be changed from one to Z, Now, since carrying cost is the opposing cost to ordering cost in this analysis, the behaviour of ordering cost w.r.t. ordering frequency is to be studied under the policies of these two extreme ordering policies. This can be depied as under –

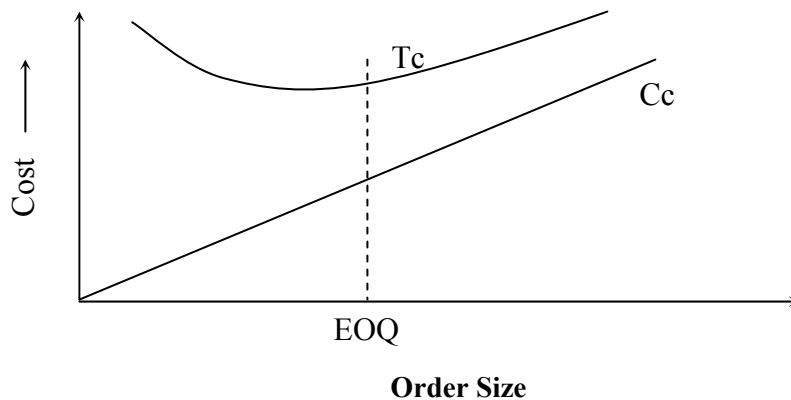


(Inventory behaviour under certainly with constant rate of demand)

with such pattern of inventory, the average amount is stock during the entire period will be simply $x/2$. Thus all z items are ordered once the large average inventory throughout period $z/2$. If one unit per order is executed then $1/2$ unit in stock in average will exist.

Therefore carrying cost $\propto \frac{1}{\text{Ordering cost}}$

Thus the total cost will comprise of order cost and stock holding cost (Cc)



Say

X_0	=	Optimal order size
Z	=	Demand in a period, in units
X	=	Amount to order, in units
C	=	Per unit cost of the item
Cr	=	Cost per order or set up cost
Cc	=	% cost, tied up money for a period per item
Zc	=	Stock of cost, purchased.

Then X units per order gives $\frac{Z}{X}$ orders

\therefore Order cost = $Cr (Z/X)$

and $X/2$ remains the average inventory stock

$$\text{Carrying Cost} = \frac{X}{2} C Cc$$

$$\text{Total Cost, } Tc = \frac{Z Cr}{X} + \frac{X C Cc}{2} + ZC$$

$$\frac{d(TC)}{dx} = 0 - \frac{d(ZCc)}{dx} + \frac{d(XCCc)}{dx} \cdot \frac{1}{Z}$$

Economic Order Quantity EOQ or Optimal

$$\text{-Order size, } X_0 = \sqrt{\frac{2ZCr}{C Cc}} \text{ units}$$

$$\text{Or square Root EOQ} = X_0 C = X = \sqrt{\frac{2 C Z Cr}{C c}}, Rs$$

The number of orders in a given period of

$$\text{Time, } n = Z/X_0 = \frac{Z}{\sqrt{\frac{2ZCr}{C Cc}}} = \sqrt{\frac{Z C c C}{2 Cr}}, \text{ in one year}$$

$$\therefore \text{Month, } t = \frac{12}{n} = \frac{12X_0}{Z} = \sqrt{\frac{144 \cdot 2 \cdot Cr}{Z C c C}} = \sqrt{\frac{288 Cr}{Z C c C}}$$

In such endeavour, always reduce the number of ordering attempts and in many cases, the number of orders are rounded off to whole number of t . The total cost written in terms of months between order t .

$$TC_1 = \frac{12 Cr}{t} + \frac{t Z C Cc}{24}$$

If d is the fraction of month, Then

$$T_{t+d} = \frac{12 Cr}{t+d} + \frac{t Z C Cc}{24} + \frac{d Z C Cc}{24}$$

If t is the optimal value then, $TC_t < TC_{td}$

$$\begin{aligned} \text{Than, } (TC_{++d} - TC) &= \frac{12 Cr}{++d} + \frac{+Z C Cc}{24} + \frac{d Z C Cc}{24} - \frac{12 Cr}{t} - \frac{t Z C Cc}{24} \\ &= 12C_r \left(\frac{1}{t+d} - \frac{1}{t} \right) + \frac{d Z C Cc}{24} \\ &= 12C_r \left[\frac{1}{t+d} - \frac{1}{t} + \frac{Z C Cc d}{288 C_r} \right] \end{aligned}$$

$$\text{Substituting } 12 = \frac{288 Cr}{Z C Cc}$$

$$= 12 Cr \left(\frac{1}{t+d} - \frac{1}{t} + \frac{d}{t} \right)$$

$$= 12 Cr \left[\frac{1}{(t+d)} + \frac{d-1}{t} \right]$$

$$= 12 Cr \left[\frac{d2}{t2(t+d)} \right]$$

This indicates that + ve value of deviation in JC by rounding off adjacent while number of t is always less costlier than -ve value

$$\text{Similar, } T C_{opt} = \frac{Z Cr}{X_o} + \frac{X_o C Cc}{2} = \frac{Z Cr}{\sqrt{\frac{2 Z Cr}{C Cc}}} + \frac{C Cc}{1} \sqrt{\frac{2 Z Cr}{C Cc}}$$

$$= \frac{Z Cr + \frac{C Cc}{2} \times \frac{2 Z Cr}{C Cc}}{\sqrt{\frac{2 Z Cr}{C Cc}}} = \frac{2 Z Cr}{\sqrt{\frac{2 Z Cr}{C Cc}}}$$

$$= 2 Z Cr \sqrt{\frac{C Cc}{2 Z Cr}}$$

$$= \sqrt{2 Z Cr C Cc}$$

There are many more situation where the E O Q concept has no value and there are reason to calculate an EOQ when

1. The customer specific order Quantity
2. The production run lot is limited by Equipment capacity
3. The self life of the product itself is so short
4. The run length is limited by tool life
5. Raw material batches becomes predominant to fix up the order quantity

QUANTITY DISCOUNT

In order to induce larger purchases, the supplier often offers a reduced price provided order quantity is greater than specified minimum quantity. Such cases where quantity discount are offered by the vender will be similar to the models like anticipated price changes, various other kinds of limitation, quantity discount, price discount etc.

In case of discount, transportation cost is curtailed due to sufficient cost purchased and dispatching. The inventory models are to be prepared and study the acceptance or rejection of such discounts scheme.

There are three effects or characteristic of the discount problem on total Cost, TC

1. The reduction in unit cost, TC
2. The reduction in total procurement cost due to reduction in number of placement of orders.
3. Change in carrying cost, Cc.

Thus the mathematical presentation will be on the above three effects and will decide

under which circumstances the discount should be accepted.

Say,	Z	-	Demand in period units	
	X_o	-	Optimal order size, units	
	d	-	discount	
	KX_o	-	Units required to get discount	Where $k > 1$

Three will be 3 – changes in TC as listed above,

1. $Z cd =$ Direct saving in Cost over the time unit
2. $\frac{ZCr}{KX_o} =$ Ordering cost or set up cost
3. $\frac{1}{2} KX_o C (1-d) Cc =$ Carrying cost for $K X_o$ order size

The acceptance of discount will be advantageous, only when TC of units ordering $K X_o$ minus Direct Saving in cost should be less than the minimum TC, when X_o units are ordered.

$$\frac{ZCr}{KX_o} + \frac{KX_o C(1-d) Cc}{2} - ZCd = \frac{ZCr}{X_o} + \frac{X_o C Cc}{2}$$

Substituting the optimum value of

$$X_o = \sqrt{\frac{2ZCr}{C Cc}}, \text{ we get}$$

$$\frac{ZCr}{K} \sqrt{\frac{C Cc}{2ZCr}} + \frac{K Cc C(1-d)}{2} \sqrt{\frac{2ZCr}{C Cc}} - ZCd$$

$$\leq Z Cr \sqrt{\frac{C Cc}{2 Z Cr}} + \sqrt{\frac{2 Z Cr}{C Cc}} \times \frac{C Cc}{2}$$

$$\text{or } \frac{1}{K} \sqrt{\frac{Z Cr Cc}{2}} + K (1-d) \sqrt{\frac{Z Cr C Cc}{2}} - Z C d$$

$$\leq \sqrt{\frac{Z Cr C Cc}{2}} + \sqrt{\frac{Z Cr C Cc}{2}}$$

$$\leq \sqrt{2 Z Cr C Cc}$$

$$\text{or } \frac{1}{k} + k(1-d) \leq \sqrt{2 Cr C Cc + Z Cd} \quad \sqrt{\frac{2}{Z Cr C Cc}}$$

$$\sqrt{\frac{4 Z Cr C Cc}{Z Cr C Cc}} + \sqrt{\frac{2 Z Cd}{Cr Cc}}$$

$$\leq 2 + d \sqrt{\frac{2 Z C}{Cr Cc}}$$

$$\leq 2 + d \sqrt{\frac{2 Z C}{Cr Cc}}$$

$$\text{Put } Q = \sqrt{\frac{Z C Z}{Cr Cc}}, \text{ for Convenience}$$

$$\text{Then } \frac{1}{K} + k (1-d) \leq Q d + 2$$

$$\text{Or } 1 + k^2 (1-d) - Q dk - 2 k \leq 0$$

$$\text{Analogus } (1-d) k^2 - (2 + Qd) k + 1 \leq 0$$

$$\therefore K = \frac{(2 + Qd) \pm \sqrt{(2 + Qd)^2 - 4(1-d)}}{2(1-d)}$$

We want k to be as large as possible, and the break even point for any, discount, is given by deleting -ve valaue

$$\therefore K = \frac{(2 + Qd) + \sqrt{(2 + Qd)^2 - 4(1-d)}}{2(1-d)}$$

Thus for any given values of Cc and Cr, table can be prepared for breakeven value of K. like Ce = 0.12 per year, Cr = Rs 10, we have

Breakeven value of k

Cz	D		
	0.01	0.02	0.05
1000	1.901	2.458	3.991
5000	2.521	3.576	6.642

10000	2.986	4.446	8.78
-------	-------	-------	------

Where $C_z = R_s$ demand value for the value

If the amount which must be ordered to obtain the discount Z , X then discount after should be accepted, otherwise, the usual X_0 units should be ordered.

Ex. A Contractor has a requirement of cement that amount to 150 bages per day. No shortages are allowed. Cement cost Rs 120 per bag. Holding cost is Rs 2 per bag per day cost Rs 150 to process an order.

Find

- i) Optimal lot size
- ii) Minimum Procurement level i.e. Recover point, if lead time is 3 days
- iii) Calculate total system cost day
- iv) Sketch out the inventory process.

SOLUTION :-

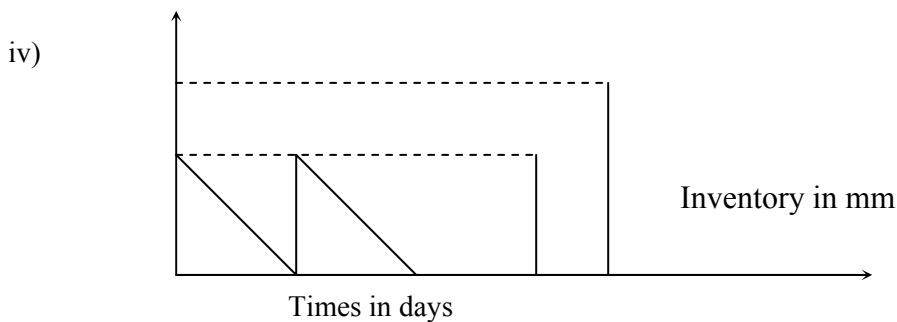
$$i) X_0 = \sqrt{\frac{2Z Cr}{C Cc}} = \sqrt{\frac{2 \times 150 \times 150}{2 \times 120}} = \sqrt{\frac{150 \times 150}{120}} = 13.69$$

$$ii) \text{Procurement level} = 150 \times 3 = 450 \text{ bags}$$

$$iii) T E S C = 150 \times 120 + \sqrt{2 Z Cr C Cc}$$

$$= 18,000 + \sqrt{2 \cdot 150 \cdot 150 \cdot 120 \cdot 2}$$

$$= 21,286.335 \text{ Rs per day}$$



Ex A Company uses a special bracket in the products which an orders from outside suppliers. The appropriate data are

Demand 2000 per annum

ordering Cost Rs 20 per order

Carrying cost 20% of item price

Basic item price Rs 10 per bracket.

The company is offered the following discounts on the basic price.

For order Quantity 400 – 799 less 2%

800 – 1599 less 4%

1600 and above 5%

It is required to establish the most economic quantity to order

SOLUTION :-

$$EOQ = \sqrt{\frac{2ZCr}{CCc}} - \sqrt{\frac{2 \times 2000 \times 20}{10 \times 0.2}} = 200 \text{ brackets}$$

$$Q = \sqrt{\frac{2ZC}{CrCc}}, \text{ for Convenience } \sqrt{\frac{2 \times 10 \times 2000}{20 \times 2}} = 31.62$$

$$\text{Break Even value of } K \sqrt{\frac{2 \times 10 \times 400}{4}} = 44.72, \sqrt{5 \times 800} = 63.24$$

$$\sqrt{5 \times 1600} = 89.41$$

Z	200	400	800	1600
	d	02	0.04	0.05
200				
400		$2.55 \times X_0 = 510$	897	
800		$2.99 \times X_0 = 598$		
1600		$3.58 \times X_0 = 716$	1125	1330

$CZ > KX_0C$ accepted

SECOND NUMBER

Order Qty	$X_0 - 200$	400	800	1600
Discount	-	2%	4%	5%
Avg No of orders	10	5	2.5	1.25
Saving in orders	--	5	7.5	8.75
Saving p.a.	--	100	150	175
Price Saving	--	400	800	1000
Per item p.a.				
Total Gains		500	950	1175

Avg Cc p.a. 200 392 768 1520

Additional Cost -- 192 568 1320

Incurred

Net Gains	--	308	382	--
Net loss	--	--	--	145

DYNAMIC INVENTORY UNDER RISK :-

It can be Characterised as under –

- (a) The under stock Cost, C_u is opposing directly, C_c , Carrying cost of reserve stock neglecting over stock cost.
- (b) The ordering cost, C_r , directly proportional to the carrying cost, C_c
- (c) The time lag is taken explicitly into account.

GENERAL CHARACTERISTICS :-

1. There is a possibility of executing number of orders.
2. There is known probability distribution of demand.
3. This probability distribution is in terms of some interval of time.
4. The ordering cost is involved
5. Also carrying cost is involved
6. The under stock cost is involved
7. Whereas overstock cost is involved but in most of cases neglected, being a period involved of unlimited nature.

BASIC KINDS OF CONTROL SYSTEM :-

There are two controllable variables.

1. Frequency of ordering
2. Amount to be ordered

We are not sure about the

Varying the frequency of ordering.

These two possibilities results in to two systems.

Fixed order quantity system (Two bin system) Base stock Q-system :

This system has a fixed order size and let the frequency of ordering be determined by the fluctuation in demand. Some quantity of stock is to be ordered out, keeping in mind the time lag between order and delivery. Whenever the stock on hand falls to this minimum level be given order is immediately placed. This system is in use of for a long time and so called as two bin.

System i.e. two bins are provided for each item, theoretically. Often, the second bin will be used after finishing the item from first one and fresh order is placed.

The major disadvantage of this system is that it requires continuous perpetual auditing of the inventory on hand.

Q – System – Has

1. Fixed order size
2. Varying order period, due to fluctuation
3. When the stock on hand falls below the predetermined level, the order is placed i.e. placed the Min stock level.
4. There is a time lag between order and delivery.
5. No need of Buffer stock (Reserve Stock)
6. Average order period = $\frac{\text{Demand in Average in time}}{\text{Fixed order size}}$

On the above characteristics the optimal system is discovered. To find out the solution or desired policy.

Use optimal lot size formula for Average demand which will give optional number of orders and fixed

order quantity i.e. Dynamic-certainly case $X_o = \sqrt{\frac{2ZCr}{CCc}}$

Separately determine the optimal reserve stock during lag period by the method of static inventory – under risk.

FIXED ORDER PERIOD (FIXED INTERNAL):-

In this – P system, the order period is determined by analysis and then the item in inventory is reviewed. The order quantity will vary in accordance with the active inventory. The total size of order will be different after adding the seasonal the demand with average inventory. If the central stock record is maintained it become very to fix up the order quantity after periodic review.

If we have an average order period of t weeks then

$$(i) \text{ Ordering Cost} = \frac{52Cr}{t}$$

(ii) Carrying cost for Average demand

$$= \frac{+D, C.Cc \text{ Where}}{104} \quad D = \text{Demand / year}$$

$$Z = \text{Average Weekly demand} = D$$

(iii) Carrying cost for safety reserve

$$W C C_e \text{ where } W = \text{safety reserve during lead time}$$

$$R = \text{Average demand in lead period}$$

(iv) Out of stock per year

$$= \frac{52 K}{1} \times f(y) dy$$

$$R + W$$

Where K = fixed out of cost

∴ Total cost, TC = i + ii + iii + iv

$$= \frac{52 Cr}{t} + \frac{t D C C c}{104} + W C C c + \frac{52 K}{t} f(y) dy$$

$$R + W$$

Equation (19) must be minimized by differentiating w. r. to t & w to equal too

$$\frac{dTC}{dW} = C C c, \quad - \frac{52 K}{t} f(R+W) = 0$$

Equation these two equation and solving by iteration (3 Nos) for t, we get.

$$(f(R+W))^2 = \frac{2 C C c (Cr + K (1 - F(R+W)))}{DK^2} \text{ ----- } 20$$

P – System – Has :-

1. Fixed order period
2. Varying order size
3. Order amount will be determined
4. If order period is less than lead time, then units on hand plus units on order but not received is to be considered.
5. Fluctuation in demand will be taken care by stock carried forward.
6. Whereas, Reserve stock is to be neglected during a period of lead time.

∴ Total Cost, TC = 1) Yearly ordering cost
 + 2) Yearly Cc for the stock to meet average demand
 + 3) Yearly Cc of reserve
 + 4) Yearly out of stock cost

Here, we are assuming that the demand distribution is known for a basic one week period.

- If Z = Average weekly demand
 LT = Lead time
 X = Order quantity
 X
 -- = order period in weeks.

The demand distribution for this number of weeks plus the LT is convolution of the basic distribution.

$$F\left(\frac{1}{Z} + ET\right) f(y) dy, \text{ to the } \left(\frac{1}{Z} + ET\right)$$

Convolution of the basic demand distribution.

Then,

$$\begin{aligned} TC &= \frac{52 Z C_c}{x} + \frac{X C C_c}{2} + t_c C_c + \frac{52 Z K}{X} f \frac{f}{6} + LT \int (y) dy \quad \text{----- (21)} \\ &= \left(\frac{1}{Z} + ET\right) Z + r \end{aligned}$$

CHEMICAL TECHNOLOGY

1. Emerging role of the paint industry in improving human health
2. Role of software in Chemical Engg.
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