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**CHAPTER-3**

**Production Planning and Control**

**Meaning of Production Planning and Control:**

PPC is a very critical decision which is necessarily required to ensure an efficient and economical production. Planned production is an important feature of any manufacturing industry. Production planning and control (PPC) is a tool to coordinate and integrate the entire manufacturing activities in a production system. This essentially comprises of planning production before actual production activities start and then exercising control over those activities to ensure that the planned production is realized in terms of quantity, quality, delivery schedule and cost of production. According to Gorden and Carson, PPC usually involve the organization and planning of manufacturing process. Principally, it includes entire organization. The various activities involved in production planning are designing the product, determining the equipment and capacity requirement, designing the layout of physical facilities and material and material handling system, determining the sequence of operations and the nature of the operations to be performed along with time requirements and specifying certain production and quantity and quality levels. Production planning also includes the plans of routing, scheduling, dispatching inspection, and coordination, control of materials, methods machines, tools and operating times. Its ultimate objective is the to plan and control the supply and movement of materials and labour, machines utilization and related activities, in order to bring about the desired manufacturing results in terms of quality, quantity, time and place. This provides a physical system together with a set of operating guidelines for efficient conversion of raw materials, human skills and other inputs to finished product.

**Procedure of Production Planning and Control**:

 The PPC is entirely based on the pre-design format. It attempts to execute and implement all activities/operations according to the set plan. All operations should be executed in a proper manner with a close vigil on all facts ensuring that the time period and the stipulated costs should not go beyond the reach and it should be done under the excepted/agreed policies. These costs are including the cost of assets, capital cost of the facility, and labour. The PPC consists of the following steps.

a) Forecasting the demands of the customers for the products and services.

 b) In advance preparing the production budget.

c) Design the facility layout.

d) Specify the types of machines and equipment.

e) Appropriate production requirements of the raw materials, labour, and machinery.

 f) Drawing the apt schedule of the production.

g) Confirming the shortage or any excess of the end product.

h) Future plans are drawn for any sudden surge in the demand for the product.

i) The rate and scale of production is setup. Which needs to be broken into realistic time periods and scheduling. The specified job needs to be done in the amount of time provided so that the production can move to next step.

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PPC essentially consists of three Stages:

a) Planning stage

b) Action stage

c) Monitoring stage

All these three stages are very important from the point of view to production because without planning no production work can take off at all. The foremost thing which is required for any production is a proper planning.

**Elements of Production Planning and Control:**

This is important to note that production plan is the first and the foremost element of PPC. Planning refers to deciding in advance what is to be done in future. A separate planning department is established in the organization which is responsible for the preparation of policies and plans with regard to production to be undertaken in due course. The planning department prepares various charts, manuals production budgets etc., on the basis of information received from management. These plans and charts or production budgets are given practical shape by carrying various elements under production control. If production planning is defective, production control is bound to be adversely affected. For achieving the production targets, production planning provides sound basis for production control. One needs to remember that production plans are prepared in advance at top level whereas, production control is exercised at machine shop floor (bottom level) where actual production is taking place. Some important elements of PPC have been depicted in the figure as below:

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The important elements may be listed as following:

1. Materials: planning for procurement of raw material, component and spare parts in the right quantities and specifications at the right time from the right source at the right place. Purchasing, storage, inventory control, standardization, variety reduction, value analysis and inspection are the other activities associated with material.

2. Method: choosing the best method of processing form several alternatives. It also includes determining the best sequence of operations (process plan) and planning for tooling, jigs and fixtures etc.

3. Machines and equipment: manufacturing methods are related to production facilities available in production systems. It involves facilities planning, capacity planning, allocations, and utilization of plant and equipment, machines etc.

4. Manpower: planning for manpower (labour and managerial levels) having appropriate skills and expertise.

5. Routing; determining the flow of work material handling in the plant, and sequence of operations or processing steps. This is related to consideration of appropriate shop layout plant layout, temporary storage location for raw materials, component and semi-finished goods, and of materials handling system.

**Route Sheet:** a route sheet is a document providing information and instructions for converting the raw material in finished part or product. It defines each step of the production operations and lay down the precise path or route through which the product will flow during the conversion process. Route sheet contains following information:

a) The operation required at their desired sequence

b) Machines or equipment to be used for each operations

 c) Estimated set-up time and operation time per piece

 d) Tools, jigs, and fixtures required for operations

e) Detailed drawings of the part, sub-assemblies and final assemblies

 f) Specification, dimensions, tolerances, surface finishes and quality standard to be achieved

g) Specification of raw material to be used

h) Speed, feed etc. to be used in machines tools for operations to be carried on.

 i) Inspection procedure and metrology tools required for inspection

 j) Packing and handling instructions during movement of parts and subassemblies through the operation stages.

6. Estimating: Establishing operation times leading to fixations of performance standards both for worker and machines. Estimating involves deciding the quantity of the product which needs to be produced and cost involved in it on the basis of sale forecast. Estimating manpower, machine capacity and material required meeting the planned production targets are like the key activities before budgeting for resources.

7. Loading: machine loading is the process of converting operation schedule into practices in conjunctions with routing. Machine loading is the process assigning specific jobs to machines, men, or work centers based on relative priorities and capacity utilization. Loading ensures maximum possible utilization of productive facilities and avoid bottleneck in production. It’s important to either overloading or under loading the facilities, work centers or machines to ensure maximum utilization of resources.

8. Scheduling: scheduling ensure that parts and sub-assemblies and finished goods are completed as per required delivery dates. It provides a timetable for manufacturing activities. Purpose of scheduling:

a) To prevent unbalance use of time among work and centers and department.

 b) To utilize labour such a way that output is produced within established lead time or cycle time so as to deliver the products on time and complete production in minimum total cost.

9. Dispatching: This is concerned with the execution of the planning functions. It gives necessary authority to start a particular work which has already planned under routing and scheduling functions. Dispatching is release of orders and instructions for starting of production in accordance with routing sheet and scheduling charts.

 10. Inspection: This function is related to maintenance of quality in production and of evaluating the efficiency of the processes, methods and labours so that improvement can be made to achieve the quality standard set by product design.

11. Evaluating: The objective of evaluating is to improve performance. Performance of machines, processes and labour is evaluated to improve the same.

12. Cost control: Manufacturing cost is controlled by wastage reduction, value analysis, inventory control and efficient utilization of all resources.

**Requirements for an effective Production Planning and Control:**

In an organization, PPC system can be effective only if the following aspects are given due considerations before implementation:

 a) Appropriate organization structure with sufficient delegation of authority and responsibility at various levels of manpower.

b) Right person should be deputed at right place for right job.

c) Maximum level of standardization of inventory, tooling, manpower, job, workmanship, equipment, etc.

 d) Appropriate management decision for production schedule, materials controls, inventory and manpower turnover and product mix.

e) Flexible production system to adjust any changes in demand, any problem in production or availability of materials maintenance requirements, etc

 f) Estimation of accurate leads times for both manufacturing and purchase.

g) Management information system should be reliable, efficient and supporting.

h) Capacity to produce should be sufficient to meet the demand.

i) The facility should be responsive enough to produce new products change of products mix and be able to change the production rates.

The above elements are very important and necessary to make the production planning system effective and efficient.

**Utility of PPC Productions:**

The implementation of PPC based production system yields various advantages to any organization for various functional activities, which include the following:

 a) Last hour rush is avoided: Production is well planned and controlled as per the given time schedules. Therefore, production control reduces the number of emergency order and overtime works on plant and thus reduces the overheads.

b) Problems areas of bottleneck get reduced: The incomplete work or work-in-transit does not get piled up because production control balances the line and flow of work.

 c) Cost reduction: An appropriate production control increases the men-machines utilization, which maintains in process inventories at a satisfactory level, leads to a better control on raw material inventories, reduces costs of storage and materials handling, helps in maintaining quality and limits rejections and thus ultimately reduces the unit cost of production.

d) Optimum utilization of resources: It reduces the time loss of the workers waiting for materials and makes most effectives use of equipment.

 e) Better coordination of plants activities: PPC coordinates the activities of the plant that leads to control concerted effort by workforce.

 f) Benefits to workers: PPC results into better efficiency and productivity, which leads to adequate wages stable employment, job security, improved working conditions increased job satisfaction and ultimately high morale.

 g) Improved services to customers: PPC leads to better services to the customers as it ensures production in accordance with the time schedules and therefore, deliveries are made as per the committed schedules.

### Objectives of Demand Forecasting:

Demand forecasting constitutes an important part in making crucial business decisions.

**The objectives of demand forecasting are divided into short and long-term objectives, which are shown in figure:**

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**The objectives of demand forecasting (as shown in figure) are discussed as follows:**

**i. Short-term Objectives:**

**Include the following:**

**a. Formulating production policy:**

Helps in covering the gap between the demand and supply of the product. The demand forecasting helps in estimating the requirement of raw material in future, so that the regular supply of raw material can be maintained. It further helps in maximum utilization of resources as operations are planned according to forecasts. Similarly, human resource requirements are easily met with the help of demand forecasting.

**b. Formulating price policy:**

Refers to one of the most important objectives of demand forecasting. An organization sets prices of its products according to their demand. For example, if an economy enters into depression or recession phase, the demand for products falls. In such a case, the organization sets low prices of its products.

**c. Controlling sales:**

Helps in setting sales targets, which act as a basis for evaluating sales performance. An organization make demand forecasts for different regions and fix sales targets for each region accordingly.

**d. Arranging finance:**

Implies that the financial requirements of the enterprise are estimated with the help of demand forecasting. This helps in ensuring proper liquidity within the organization.

**ii. Long-term Objectives:**

**Include the following:**

**a. Deciding the production capacity:**

Implies that with the help of demand forecasting, an organization can determine the size of the plant required for production. The size of the plant should conform to the sales requirement of the organization.

**b. Planning long-term activities:**

Implies that demand forecasting helps in planning for long term. For example, if the forecasted demand for the organization’s products is high, then it may plan to invest in various expansion and development projects in the long term.

### ****Factors Influencing Demand Forecasting:****

Demand forecasting is a proactive process that helps in determining what products are needed where, when, and in what quantities. There are a number of factors that affect demand forecasting.

**Some of the factors that influence demand forecasting are shown in Figure:**

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**The various factors that influence demand forecasting (“as shown in Figure) are explained as follows:**

**i. Types of Goods:**

Affect the demand forecasting process to a larger extent. Goods can be producer’s goods, consumer goods, or services. Apart from this, goods can be established and new goods. Established goods are those goods which already exist in the market, whereas new goods are those which are yet to be introduced in the market.

Information regarding the demand, substitutes and level of competition of goods is known only in case of established goods. On the other hand, it is difficult to forecast demand for the new goods. Therefore, forecasting is different for different types of goods.

**ii. Competition Level:**

Influence the process of demand forecasting. In a highly competitive market, demand for products also depend on the number of competitors existing in the market. Moreover, in a highly competitive market, there is always a risk of new entrants. In such a case, demand forecasting becomes difficult and challenging.

**iii. Price of Goods:**

Acts as a major factor that influences the demand forecasting process. The demand forecasts of organizations are highly affected by change in their pricing policies. In such a scenario, it is difficult to estimate the exact demand of products.

**iv. Level of Technology:**

Constitutes an important factor in obtaining reliable demand forecasts. If there is a rapid change in technology, the existing technology or products may become obsolete. For example, there is a high decline in the demand of floppy disks with the introduction of compact disks (CDs) and pen drives for saving data in computer. In such a case, it is difficult to forecast demand for existing products in future.

**v. Economic Viewpoint:**

Play a crucial role in obtaining demand forecasts. For example, if there is a positive development in an economy, such as globalization and high level of investment, the demand forecasts of organizations would also be positive.

**Steps of Demand Forecasting:**

The Demand forecasting process of an organization can be effective only when it is conducted systematically and scientifically.

**It involves a number of steps, which are shown in Figure:**

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**The steps involved in demand forecasting (as shown in Figure) are explained as follows:**

**1. Setting the Objective:**

Refers to first and foremost step of the demand forecasting process. An organization needs to clearly state the purpose of demand forecasting before initiating it.

**Setting objective of demand forecasting involves the following:**

a. Deciding the time period of forecasting whether an organization should opt for short-term forecasting or long-term forecasting

b. Deciding whether to forecast the overall demand for a product in the market or only- for the organizations own products

c. Deciding whether to forecast the demand for the whole market or for the segment of the market

d. Deciding whether to forecast the market share of the organization

**2. Determining Time Period:**

Involves deciding the time perspective for demand forecasting. Demand can be forecasted for a long period or short period. In the short run, determinants of demand may not change significantly or may remain constant, whereas in the long run, there is a significant change in the determinants of demand. Therefore, an organization determines the time period on the basis of its set objectives.

**3. Selecting a Method for Demand Forecasting:**

Constitutes one of the most important steps of the demand forecasting process Demand can be forecasted by using various methods. The method of demand forecasting differs from organization to organization depending on the purpose of forecasting, time frame, and data requirement and its availability. Selecting the suitable method is necessary for saving time and cost and ensuring the reliability of the data.

**4. Collecting Data:**

Requires gathering primary or secondary data. Primary’ data refers to the data that is collected by researchers through observation, interviews, and questionnaires for a particular research. On the other hand, secondary data refers to the data that is collected in the past; but can be utilized in the present scenario/research work.

**5. Estimating Results:**

Involves making an estimate of the forecasted demand for predetermined years. The results should be easily interpreted and presented in a usable form. The results should be easy to understand by the readers or management of the organization.

# Process Analysis

**Definition**: Process Analysis can be understood as the rational breakdown of the production process into different phases, that turns input into output. It refers to the full-fledged analysis of the business process, which incorporates a series of logically linked routine activities, that uses the resources of the organization, to transform an object, with the aim of achieving and maintaining the process excellence.

Process Analysis is nothing but a review of the entire process flow of an organization to arrive at a thorough understanding of the process. Further, it is also helpful to set up targets for the purpose of process improvement, which is possible by eliminating unnecessary activities, reduce wastage and increasing efficiency. Thus, it ultimately ends up improving the overall performance of the business activities.



## Objectives of Process analysis

1. Identify the factors that make it difficult to understand the process.
2. Ascertain completeness of the process.
3. Remove bottlenecks
4. Find redundancies
5. Ascertain the allocation of resources
6. Check out process time

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**Understanding, Quality and Efficiency** are the three basic criterion, through which one can analyse the process and determine the areas that require change.

## Steps Involved in Process Analysis

* **Step 1 – Interview major participants of the process**: Discuss the participants about what they do, why they do and how they do it. Identify the information and inputs required by the workers to perform the task assigned to them. Research about the source of input and outputs of each task.
* **Step 2 – Carry out group discussion**: Group interview and brainstorming session are conducted, with the aim of generating ideas, validating and refining the information collected, at the first step.
* **Step 3 – Identify bottlenecks and redundancies**: Find out the bottlenecks in each task that causes delay and various measures to remove it. Further, identify the unnecessary activities, whose elimination can ease the process.
* **Step 4 – Create Sketch**: Make a sketch right from the scratch of the entire process, depending upon the business process requirements, which came into light after interviews and discussions.
* **Step 5 – Compare**: At the end, compare the latest process flow with the previous one, and mark the areas that require changes, as per the research conducted.

Process Analysis is a methodical approach to enhance the understanding and redesigning of the workflow of the organization. It acts as a tool to maintain and improve the business processes and also help in attaining the incremental to transformational benefits, such as cost reduction, optimum utilisation of resources, effective human resource allocation and process efficiency.

# Production Scheduling

Production and manufacturing run on timelines. You receive orders, sometimes concurrently, and you plan the steps in your manufacturing schedule to ensure parts of the process are completed in proper sequence as efficiently as possible. Creating an effective and efficient production schedule can cut payroll costs and keep frustration to a minimum.

## Areas of Production Scheduling

* **Procurement:** Production can't proceed if you don't have the materials necessary for manufacturing. Procurement scheduling is an art and a science that involves keeping enough on hand without carrying a bloated inventory. You can tighten procurement systems by using digital or manual spreadsheets to track inventory and by developing relationships with suppliers who can get you what you need consistently and quickly.
* **Personnel:** Planning and scheduling employee time is critical to developing a successful production work flow plan. There should be enough workers on hand to finish projects within the promised time frame but not enough to bloat your payroll or create inefficiencies by crowding your work space. It helps to understand the strengths and weaknesses of each staff member so you can leverage employee skills and circumvent potential difficulties.
* **Machinery:** Like your employees, your equipment has a limited number of capacity hours that should be scheduled thoughtfully. Machines should be well maintained according to a schedule that doesn't take them out of production any longer than necessary.

## Tools for Scheduling Production

* **Software:** Once the logistics of your production schedule become complex enough to bog you down, there is a range of software options available to help you manage the details. Programs such as Monday.com and Protected Flow Manufacturing help you to set priorities, coordinate processes and manage staffing.
* **Written documents:** If your production processes are relatively simple, you may be able to effectively create useful and meaningful lists so team members and managers have a clear idea of what needs to happen and in what order.  Timelines and flow charts can help to provide useful visuals to help staff understand how processes interface.
* **Custom spreadsheets:** You can also design your own spreadsheets to plan and communicate work flow. Custom spreadsheets offer the advantage of being tailored specifically to your company and your processes. They pose the disadvantage of potentially being less robust or nimble than a software system designed by professionals drawing on a deeper and broader database of scheduling tools and knowledge.

## Obstacles to Effective Production Scheduling

* **Poor communication:** No matter how good your production scheduling, it won't be effective unless your crew is kept in the loop and knows what needs to be done. Your team should have systems in place for conveying an overall plan and also relaying updates.
* **Outdated systems:** If your business is growing at a healthy clip, your systems and software will periodically become obsolete because the processes they manage will be continually evolving. For successful production scheduling, evaluate your processes and information systems periodically and update them as needed.
* **Unreliable vendors:** If your vendors don't come through with the materials you need in the time frame they promised, you could find yourself with people and machinery scheduled for processes that cannot move forward. When you need inventory urgently, make sure your vendors know that timing is critical. If they consistently don't come through for you when you need them, find other vendors.

## The Importance of Strategy

Production scheduling isn't simply a matter of laying out steps and then waiting for the work to happen. Your entire approach to your manufacturing schedule should be organized around systems and processes that specifically make sense for your business. Decide whether it makes more sense for your company to stay well ahead of the game to aggressively avoid shortfalls or whether you prefer the tightness of a lean manufacturing approach. Track the success of different strategies and collaborate with coworkers to build a shared knowledge base.

## Production Scheduling Techniques

Production scheduling involves coordinating the logistics of the manufacturing process so work is completed on schedule while wasting as few resources as possible. To schedule production effectively, you first need to **make sure you have all of the materials** you need to proceed. If you're missing the items you need to complete a particular step in the process, you may end up shutting down your entire production operation until they arrive because other steps may depend on the one that cannot be completed.

You must also have **personnel scheduled effectively** for your production to proceed smoothly. There should be enough staff on the floor for each stage in the process, and they must be trained and skilled to perform the work that needs to be done. Although you must have enough employees scheduled to get the job done, you should also avoid scheduling too many because this is a waste of resources, and having too many workers on-site can actually cause congestion and interfere with productivity.

Your production scheduling should also cover the **equipment** necessary to perform manufacturing tasks. Machinery that is shared by different parts of your operation should be available when it's needed for a particular process, and maintenance should be scheduled so it is in good working order. If equipment is shared among different departments or for production of different product lines, managers and schedulers should communicate to make sure there is no overlap or competition for resources.

## Master Production Scheduling

Production planning involves logistics specific to manufacturing, such as orders, inventory and availability of personnel. However, your production planning occurs within the larger context of scheduling and planning for your entire company. Master production scheduling is a **long-range approach** to planning that integrates the timing for manufacturing each product into a larger plan that also takes into account product mix, capacity and availability of raw materials.

For example, your business may be working on a long-term plan to phase out some product lines that show consistent demand but earn relatively low margins. Rather than discontinuing these products all at once and alienating the customers who depend on them, you may instead choose to do a production run that uses up materials inventory devoted exclusively to these products, such as custom-printed packaging.

Your master scheduling plan might look for an opportunity to complete this production during a time of year when seasonal demand for other products typically declines. This will allow you to absorb excess staffing capacity and also use extra capacity on your production line while using up materials you would otherwise discard. This approach would also benefit loyal customers, giving them fair warning and an opportunity to shop around for a replacement product rather than cutting them off all at once.

## Implementing Detailed Scheduling

Detailed scheduling, or manufacturing scheduling, gets down to planning and scheduling week by week, day by day and even hour by hour. This process works in tandem with master scheduling, filling in the details and working out the logistics of what will get done and when it will take place within the longer-term schedule that has been set.

Unlike master scheduling, which creates broad timelines over an extended period, **detailed scheduling syncs with specific orders.** These include both customer orders to be fulfilled and inventory orders that must be on hand before manufacturing can commence. Because it is nearly impossible to know many of these details far ahead of time, detailed scheduling works to connect puzzle pieces as specifics unfold.

Detailed scheduling is especially critical with a lean or just-in-time production orientation, which is based on agile adaptations and skillful timing to make the most of both material and human resources. To practice lean manufacturing effectively, your business must plan its inventory purchases and employee schedules with an eye toward throughput, or filling specific orders as they arrive, while minimizing bottlenecks.

## Forecasting Techniques for Production Planning

Forecasting is necessary for effective production planning because it gives you the necessary information to create action steps. Of course, there is no way to forecast future orders with complete certainty. However, these techniques of production control can help you develop as complete and accurate a picture as possible of how much you will need to produce and when you will need to produce it.

* **Forecasting orders.** If you can forecast upcoming orders reasonably closely, you can have the materials on hand and the necessary staff scheduled to meet demand. Order forecasts can be based on seasonal fluctuations and patterns from previous years. They may also be tied to planned promotions that will foster interest in your products.
* **Forecasting staff.** Staffing forecasts depend on order forecasts. Having a reasonably accurate idea of how much you will need to produce during an approaching time frame will allow you to calculate how many staffing hours are necessary to get the job done and to make sure that the necessary personnel are scheduled.
* **Forecasting production time.** The better you understand your manufacturing processes and the amount of time they take, the better you'll be able to keep your customers satisfied by creating realistic expectations for order delivery. Base timeline forecasts on past performance and factor in variables such as improved processes or supply chain difficulties.

## Forecasting Inventory Process

If you have the inventory you need on hand, you'll be able to start production right away once your customers place their orders. However, having too much inventory on hand can tie up working capital that you may need for more urgent expenses, such as rent and payroll. In addition, if you make large inventory purchases and your customers' order patterns don't sync with your forecasts, you may waste money and get stuck with items you can't use.

A **just-in-time approach** to inventory planning involves cutting it close and ordering as late as possible relative to when you need to have the items in stock. This approach has many advantages, such as reducing waste and improving efficiency. However, it takes skill and practice to truly understand the rhythm of orders and purchasing. It is sometimes better to have some extra inventory on hand to avoid running out than to risk running your stock down too low and missing the opportunity to fulfill an important order.

The process of forecasting inventory will depend on the time it takes between ordering and receiving a particular material and also whether that item is available from multiple sources. You have a lot more flexibility with a part or component that you can order one day and receive the next than with one that takes several weeks to arrive. In addition, if you can only get a critical item from a single vendor, you should order extra proactively, keeping with that vendor's delivery timeline.

## Planning Your Personnel

Unlike your inventory and your machinery, your workers have personal lives that they need to coordinate with their work schedule. You need to plan when to schedule worker hours for optimum production efficiency, and your workers need to know their schedules so they can plan how their work hours will integrate with their family obligations and recreational needs.

In theory, it would be most efficient for your business to wait and see what orders come in and then plan employee schedules at the last minute to avoid short staffing and redundancies. In practice, however, your employees need **advance notice** and some degree of consistency so they can plan their nonwork activities and count on your company for a reliable income.

If your business needs to have employees available and ready to work when important orders arrive, it makes sense to find other tasks for them when work is sparse, such as making infrastructure improvements or building skills and knowledge. This approach will cost you extra money in the short term because you'll be paying for hours that aren't strictly tied to current production. However, the benefit of having a trained staff that is ready to work may easily outweigh the short-term expense.

## The Big Picture

Your approach to production planning will depend on your company's longer-term and bigger-picture objectives.

* **Customer service.** If your company takes special pride in going the extra mile to meet customers' needs, your production planning orientation will focus on being able to pivot when an urgent order comes in or reconfigure for special circumstances. In this case, your production planning will depend on building flexibility into your systems so you can make these changes when necessary.
* **Profitability.** If your business is geared toward cutting costs and maximizing profitability, your production planning will emphasize efficiency. Whether this takes the form of following lean manufacturing principles or building up finished inventory when you have the capacity, you should gather data diligently and continuously to assess whether you are meeting your financial goals.
* **Lifestyle choices.** You may choose to organize your production planning to maximize quality of life for your employees. This approach makes particular sense for a worker-owned company. Even if you plan your processes with an eye toward interfacing work processes with employee personal needs, you'll still need to make a profit, or you won't be able to sustain this approach over the long term.

## Benefits of Production Scheduling

Effective production scheduling makes your business run more smoothly and profitably. When this planning is done well, your staff will have the materials they need to work efficiently without unnecessary down time from supply chain interruptions or overlapping demand for equipment. Your bottom line will benefit from the reduced waste, especially in personnel costs, as your activities are more carefully coordinated.

Your customers will also be happier if you do a good job of scheduling your production routines. They'll receive their orders on schedule with fewer wild cards due to missed deadlines and costs due to inefficiency that you may pass along. Satisfied customers lead to repeat orders, making your business more profitable overall.

Production planning also benefits your employees, who can count on more predictable schedules. Advance planning and notice without unwelcome surprises make it easier for them to coordinate their job responsibilities and personal lives, and smooth production runs prevent unnecessary, unscheduled overtime that interferes with family time. Effective production scheduling can even lead to higher pay if your company becomes more profitable and opts to invest in its workforce and increase retention of skilled and experienced personnel.

**CHAPTER-4**

**WORK MEASUREMENT: CONCEPT AND OBJECTIVES:**

Work measurement is concerned with the determination of the amount of time required to perform a unit of work. The time required for this task is commonly referred to as the ‘standard’ or ‘allowed time’. Thus, work measurement provides a yardstick for human effort, which can help in efficient staffing, improved planning and control and sound incentive schemes. The International Labour Organisation (1974), defines work measurement as “the application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance.” The Work Study Report of the Secretariat Training School, Ministry of Home Affairs, Government of India (1966) defines it as “the application of techniques designed to establish the work content of a specified task by determining the time required for carrying it out at a defined standard of performance by qualified worker”. Work measurement is thus a device for estimating more precisely the amount of time it should take or will take to perform the assigned work. Work measurement has negative and positive roles. Negatively, it locates the existence of ineffective time; positively it sets standard time for the performance of work. Since method study is a technique for reducing work content, therefore, it is necessary that method study should precede work measurement. In short, work measurement aims at investigating, reducing and subsequently eliminating ineffective time. It is very easy to apply this technique to highly repetitive operations. It is considered difficult, to apply this technique to work pertaining to key administrative posts, work with unpredictable results and those which need special requirements. However, we must try to use this technique even under such situations through establishing norms or standards of performance which may be less precise but rational. Work measurement is concerned with investigating, reducing and eliminating ineffective time in work performance. Besides, it also helps in setting performance standards which connote, the optimum rate of output that can be achieved by a qualified worker on an average in a working day with due allowance being made for the necessary time required for rest. The following objectives are fulfilled through the application of work measurement in an organisation:

* 1. **Comparing Alternative Methods** : There are generally many methods to perform a given job. Where two alternative methods seem equally good and suitable, the one, which consumes less time for completion, is considered better. The techniques of work measurement offer the best means of making this choice.
	2. **Determine the Staffing Pattern**: Staffing is an important area of management. Work measurement can help in making the public organisations staffed by persons in right quantity and quality. Most of the committees and commissions have reported that government offices are over-staffed to a great extent but they have not offered any method by which to assess and curtail the staff.
	3. **Effective Planning and Scheduling of Operations:** Effective planning and scheduling of operations require the exact estimation and availability of resources – personnel, money and material. All these can be made possible through the technique of work measurement as the information generated by this technique forms a reliable basis for planning and forward loading the personnel and material for the administrators to utilise them to their best advantage. The main cause of the failure of the planning in India has been the lack of any accurate measurement of work. Unless the work has been measured, it cannot be planned and scheduled with any assurance that a promised operation can be executed.
	4. **Effective Means of Control** : Once the operations have been planned, then they are to be implemented to ensure the pre-designed output. Maintenance of proper records for all types of activities, and data pertaining to performance, which is maintained while work is being done, form a reliable basis for control.
	5. **Helpful in Cost Estimation:** Standards are helpful in determining the cost of the work performed. This facilitates management in preparing budgets and measuring the effectiveness of forecasts. By knowing what the cost should be and comparing them with budget figures, it is possible to ascertain the reasons for the difference. This may mean that there is a need for devising more efficient procedures and setting new standards to conform to them. Thus, standards help in reducing costs.
	6. **Better Staff Morale**: It creates better morale among staff through their perception of what is expected of them in terms of quantity and quality. The efficient staff can be separated from the inefficient and thus the work of efficient workers can be recognised. This is also helpful in installing incentive wage system. 7. Measures of Efficiency Standards serve as a basis for measuring the effectiveness of any organisation by indicating the achievements as compared with the standards. 8. Better Management On the basis of certain set standards, managerial functions can be predicted and discharged more effectively.
	7. **Measures of Efficiency**: Standards serve as a basis for measuring the effectiveness of any organisation by indicating the achievements as compared with the standards.
	8. **Better Management**: On the basis of certain set standards, managerial functions can be predicted and discharged more effectively.
	9. **Direction to Future Research**: The standards, which are laid down give clue to the problem areas where research may be carried out to solve the problem.

**ESSENTIALS OF WORK MEASUREMENT:**

Besides the competence, the personnel doing work measurement must ensure the congenial environment within the organisation where work improvement programmes are being launched. The persons conducting work measurement must possess commonsense, imagination, patience, enthusiasm, tact and above all a pleasing personality. Let us discuss some of these factors, which may be kept in mind by the persons undertaking work measurement and the top management to ensure the best results.

**a. Cordial Relationship** Work study team must establish cordial and equitable relationship with the persons working in the organisation being investigated. This would generate harmonious relationships advantageous to both sides. The study team should constantly endeavour to dispel the impression that they would devise anti-staff policies and measures. There should be mutual trust, sincerity, devotion, loyalty and an open attitude.

**b. In-built Reliability, Consistency and Uniformity** The work study team should not suggest superficial suggestions, but ensure that the standards meet the criteria of reliability, consistency and uniformity. The organisation must provide the coercive measures in case of deviation so that the system can operate well.

**c. Incentive Opportunity** The management must ensure provision of incentives to those who can ensure more efficiency and productivity as compared to the standards framed. This would encourage the keen workers to progress fast rather than allowing them to frustrate. .

**d. Participative Management** Before enforcing the new standards, we must ensure their acceptance by all the employees in the organisation through participative management or management by objectives. There is a fear that the employees may resist and even resort to strikes, etc. if not taken in confidence. Such standards would be accepted whole-heartedly and would produce best results.

**e. Cost Benefit Analysis** A huge cost is incurred in carrying out the work measurement programmes and ultimately maintaining such programmes. As a result of such an investment there should be certain benefits and saving over a period of time. The initial costs may tend to 5 increase, but they should soon level off to a point where savings should inevitably crop up.

**f. Careful Selection of the Work Measurement Team** The success of the measures of work measurement programmes depends to a great extent upon the right skills and attitudes of the personnel associated with the team. Only properly trained and experienced personnel in the relevant field should be chosen. Measurement is a practical job and it requires a competent and experienced person.

**WORK MEASUREMENT: BASIC STEPS:**

There are certain important basic steps in performing a complete work study. Some of them are relevant for method study, while these and some others are relevant for work measurement. Isolating those steps, which are necessary for work measurement, the basic procedure could easily be formulated. The essence of work measurement, would rely upon selecting the requisite unit of measurement. A standard unit of measurement should be comparable, exact and stable. The measurement of all work done in an organisation could be carried out through by any of the three ways i.e. individual output, groups on routine work and groups on special work. It includes certain basic steps as follows:

Select the work to be studied.

Record all the relevant data relating to the circumstances in which the work is being done, the methods and the elements of activity in them.

Measure each element in terms of time over a sufficient number of cycles of activity to ensure that a representative picture has been obtained.

Examine the recorded data and element times critically to ensure that unproductive or random elements are separated from productive elements; the recorded times of each element and determine a representative time for each.

Compile time for the operation, which will provide a realistic standard of performance and will include time allowances to cover suitable rest, personal needs, contingencies, etc.

Define precisely the series of activities and method of operation for which the time has been allowed and issue the time as standard for the activities and methods specified.

**WORK MEASUREMENT TECHNIQUES:**

We shall now discuss some important techniques of work measurement.

**1. Subjective Judgment** :Here work measurement involves the subjective judgment of the management, i.e., experience and guess work. This is generally known as rule of thumb standard. It is very difficult to apply these standards universally and in large-scale organisations. Moreover, these cannot be justified on scientific grounds.

**2. Record of Past Performance** :These represent what is rather than what should be. Standards thus arrived are indicators of work and time requirement and can be used for controlling the operations. It may be calculated as follows:

**Staff members Minutes per unit = (Total Number of staff members considered X Minutes in work week)/ Weighted number of units completed**.

**3. Scientific Methods:** There are many scientific methods. These are:

1. Time Study

 2. Pre-determined Motion Time Systems (PMTS)

3. Activity Sampling

4. Analytical Estimating

 5. Synthesis

 **1. Time Study** :Time study is the most important technique of work measurement. It is concerned with the direct observation of work while it is being performed. Let us define the concept of time study as applicable to work measurement. According to I.L.O (1974), “Time Study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions, and for analysing the data so as to obtain the time necessary for carrying out the job at a defined level of performance”. In a document issued by Secretariat Training School, Ministry of Home Affairs, Government of India(1966), it is stated that “Time Study is a technique for determining as accurately as possible from a limited number of observations the time necessary to carry out a given activity at a defined standard of performance.” According to J.A. Larkin, (1969), time study is “a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions, and for analysing the data so as to obtain the time necessary for carrying out the job at a defined level of performance.” The basic steps in the time study procedure have been depicted as follows. i) This is said to permit the rate of working to be assessed more accurately than would be possible if the assessments were made over a complete cycle. The operator may not work at the same pace throughout the cycle and may tend to perform some elements faster than others. ii) Enable the different types of elements to be identified and distinguished, so that each may be accorded the treatment appropriate to its type. iii) Enable elements involving high fatigue to be isolated and to make the allocation of fatigue allowances more accurate. iv) Facilitate checking the method so that the subsequent omission or insertion of elements may be detected quickly. This may become necessary if at a future date the time standard for the job is queried. v) Enable a detailed work specification to be produced. vi) Enable time values for frequently recurring elements, such as the operation of machine controls or loading and unloading work pieces from fixtures, to be extracted and used in the compilation of synthetic data. When the above preliminaries are taken care of, the actual measurements can begin. The basic time study equipments are: (i) Stop-watch (ii) A Study board (iii) Pencils (jotting down equipment) (iv) Time Study forms (v) Slide rule (for speeding up calculations), and (vi) Measuring instruments for distance and speed such as rulers, tapes micrometer, technometer, (revolution counter) etc.

**2. Pre-Determined Motion Time Systems (PMTS):** It is a work measurement technique whereby time established for basic human motions are compiled to build up the time for a job as a whole at the defined level of performance. Basic human motions are tabulated with time standard for each basic human motion. When using these systems to compute the standard time for a job, the operation is first analysed into its component motions; going in much greater detail than is normally done in method study. The time corresponding to each of the minutely analysed motions is then read from tables, and the job time is obtained by adding all the individual times. To apply one of the basic systems to manual task, taking only one minute to perform may require as much as 100 minutes of analysis and computation. Advantages i) The tabulated values are ready for immediate use and do not have to be built-up within the individual organisation. ii) They are universal in character and not confined to a limited number of elements. Time standards for most of the physical activities carried out in the average factory can be built-up from the basic times. iii) They are applicable anywhere, so that, in theory, identical jobs done in different factories should have identical time standards if the work study persons setting them have been properly trained. iv) They focus attention on the method before the time can be set and offer a more precise means of recording than any other existing system. v) They are of value in training operators in new methods, since the paths of movement are precisely described. vi) Because of the detailed breakdown, changes in methods can immediately be identified. Uses of Motion – Time Measurement This method has been applied for a number of years for: 1. Developing effective methods in advance of imitating production. 2. Improving existing methods. 3. Establishing standard data. 4. Estimating. 5. Guiding product design. 6. Developing Effective tool designs. 7. Establishing time standards. 10 8. Selecting effective equipment. 9. Training supervisors to become highly methods conscious. 10. Settling grievances. 11. Research, particularly in connection with methods, learning time and performance rating. Disadvantages i) It is not scientifically possible to add times for individual small motions in the way required by the systems, as a particular motion may be influenced by preceding and succeeding motions. ii) It is uneconomic for non-repetitive jobs. iii) It requires highly trained staff.

**3. Activity Sampling**: Activity sampling is a technique in which a large number of instantaneous observations are made over a period of time, of a group of facilities, machines, and processes of workers. Each observation records what is happening at that instant and the percentages of observations recorded for a particular activity or delay is a measure of the percentage of time during which that activity or delay occurs. Rhyne and. Freeman(1986), have stated that the power of the work sampling technique lies in the theory of probability “that is a few observations taken at random from a large group (population) tend to represent the characteristics of the group.” Activity sampling is also known as ratio-delay study, observation ratio-study, snap reading method, random observation method, machine utilisation studies and activity ration studies. The technique essentially measures (i) activities and delay, (ii) certain measures manual tasks to establish a time standard for an operation. Objectives The activity sampling attempts to: i) Determine the various causes for the given degree of labour and equipment utilisation and the effect of each cause. ii) Determine the spheres in which management policies and their application needs to be studied in detail for purpose of improvements. This may suggest either necessity of method study or development of proper maintenance procedures or production planning and control system or any other such aspect of management. iii) Get a measured evaluation of a machine utilisation as a basis for decisions regarding machinery replacement or purchase of additional machines. iv) Determine operator, machine and departmental efficiency. 11 v) Establish limits of variations for operator, machine and departmental efficiency for purposes of maintaining day-to-day control over their working. vi) Determine extent of seasonal or periodic variations, if any, of workload. vii) Isolate men or machines responsible for maximum inefficiency for purposes of taking technical or administrative steps to rectify the situation. viii) Determine personal and daily allowances to be incorporated in time standards. Activity Sampling Steps i) State the objectives, purposes of the project or problem and describe in detail each item to be measured. ii) Design the study. iii) Determine the number of observations to be made and issue instructions accordingly to study team-members. This should not be made known to the object being studied. iv) Make the observations according to the plan. v) Check the accuracy or precision of the data at the end of the study. vi) Prepare report and state conclusions and recommendations. Advantages i) It can measure many of such activities as are impracticable or too costly to be measured by time study or by other work measurement techniques. ii) Unlike time study, one management analyst can collect information about simultaneous activities of a group of men or machines or both. iii) It can be learnt quickly. iv) It can be interrupted at any time without affecting the results. v) It can be used where the stopwatch is banned. Disadvantages i) It is difficult to apply this on jobs of short duration. ii) It cannot provide elemental details that can be obtained from time study. iii) It is sometimes difficult to convince the management and the workers about the validity of the result of an activity sampling.

**4. Analytical Estimating:** According to I.L.O (1974),“Analytical estimating is a work measurement technique whereby the time required to carry out elements of a job at a defined level of performance is estimated from knowledge and practical experience of the elements concerned”. This technique serves all the basic purposes of other work measurement techniques. However, it is slightly less precise owing to the greater reliance on judgment. Essential Features 1. The employment of skilled persons with experience in the work concerned as estimators. 2. Giving these persons a thorough training in work study, including both method study and time study. It is important that they should be able to recognise standard performance rates of working. 3. The making of an initial method study of the job in as much detail as it is economical. 4. Breaking down the job into elements and determining time for each element based on standard performance. Where possible, element times are derived from time study data or synthetic times. Where no such data exist, time is estimated on the basis of the estimator’s experience. 5. When all the element times at 100 rating have been determined they are added together and the total basic time for the operation is worked out. Relaxation allowances are added as a percentage of the total time. Any additional allowances are then added. The theory of analytical estimating appears simple but it is difficult to apply in practice. It must be carried out under the guidance of an expert.

**5. Synthesis**: According to an I.L.O. Publication, (1974), “Synthesis is a work measurement technique for building-up the time for a job at a defined level of performance by totaling element time obtained previously from time studies on other jobs containing the elements concerned, or from synthetic data”. Government of India Secretariat Training School Manual (1966), states, “Synthetic times (or synthesised time standards) are time standards built-up (synthesised) from element times previously obtained from direct time studies.” This is a work measurement technique for building-up the time for a job at a defined level of performance by totaling element times obtained previously from time studies on other jobs containing the elements concerned. The main purpose of the synthesis stage of the work measurement is thus to take the measured constituent parts (elements) and build them together again. The procedure of synthesis is commonly called setting-up and there are varied ways of accomplishing it. For this technique, the normal/basic times of small elements of work have to be available set out in properly indexed files. These cover manual processing or and machine activities which have been measured by time studies. 13 Provided valid data exist and the analyst identifies all the constituent elements of the job and applies this data correctly, then the resulting time standards should be as accurate as if measured by time study. When compiling synthetic times it is not important that the operations providing the basic data should have been timed under identical conditions; in particular, similar methods and equipment must have been used and the operation must have been broken into identical elements. The possibility of using data from any one study as a basis for synthesis time is one of the reasons for making a precise and full job specification at the time of issue of the time standards. Three types of elements may be encountered when compiling synthetic times: 1. Elements, which are identical from job to job. 2. Elements which are similar in nature but vary in difficulty and in the length of time necessary to perform them as the size, weight, pressure, etc., involved. 3. Elements, which are controlled by the physical or technical characteristics of the material and the process, including automatic machine elements controlled by speed, depth, etc. Advantages 1. They are usually based on data derived from a large number of studies and are thus more reliable than time derived from single study. 2. Where the elements for which synthetic times have been compiled recur repeatedly in various jobs performed in the undertaking, so that the work involved in compiling such times is justified, they often eliminate the need for prolonged individual studies, although it is usual to make a short check study after the synthetic time has been compiled in order to ensure that no activity has been overlooked. 3. They are valuable in estimating time standards for production planning and estimating for quotation purposes. 4. They are useful in planning teamwork activities such as in an assembly line or group working, as in garment making, to reduce imbalance in the early stages.

**Time Study:**
Time study is a method of measuring work for recording the times of performing a certain specific task or its elements carried out under specified conditions. An operator does same operation (task) throughout the day. Time study help to define how much time is necessary for an operator to carry out the task at a defined rate of performance.

Time study is also called work measurement. It is essential for both planning and control of operations.

According to British Standard Institute time study has been defined as “The application of techniques designed to establish the time for a qualified worker to carry out a specified job at a defined level of performance.”

**Steps in Making Time Study:**

Stop watch time is the basic technique for determining accurate time standards. They are economical for repetitive type of work. Steps in taking the time study are:

1. Select the work to be studied.
2. Obtain and record all the information available about the job, the operator and the working conditions likely to affect the time study work.
3. Breakdown the operation into elements. An element is a instinct part of a specified activity composed of one or more fundamental motions selected for convenience of observation and timing.
4. Measure the time by means of a stop watch taken by the operator to perform each element of the operation. Either continuous method or snap back method of timing could be used.
5. At the same time, assess the operators effective speed of work relative to the observer’s concept of ‘normal’ speed. This is called performance rating.
6. Adjust the observed time by rating factor to obtain normal time for each element

                                 Normal= (Observed time \*Rating)/100

1. Add the suitable allowances to compensate for fatigue, personal needs, contingencies. etc. to give standard time for each element.
2. Compute allowed time for the entire job by adding elemental standard times considering frequency of occurrence of each element.
3. Make a detailed job description describing the method for which the standard time is established.
4. Test and review standards wherever necessary.

**Motion Study: Meaning, Objectives and Procedure**

#### Meaning of Motion Study:

The propounder of this concept was Frank Gilbesth. He defined motion study as the **“Science of eliminating wastefulness resulting from ill-directed and inefficient motions”**. The main aim of motion study is to find the scheme of least wastage of labour. Subsequently, the scope of Motion Study was enlarged and it was named as Method Study.

The method of study can also be defined as **“Systematic recording and critical examination of existing and proposed ways of doing work as a means of developing and applying easier and more effective method and thereby reducing cost”**. Method Study is a technique which includes the standardisation of equipment, method and working conditions, and training of the operator to follow the standard method.

#### Objectives of Method Study/Motion Study:

**The important objectives of the motion study are:**

1. To improve the process of doing work

2. To improve the design of work place layout

3. To find the best way of doing a job

4. To ensure reduced health hazards

5. To minimise the unnecessary human movements

6. To have more effective utilisation of material, machines and workers

7. To train the individual worker in its practice as per standardised method.

#### Procedure for Motion Study:

**Motion Study can be performed in the following steps:**

**Step I: Break up the operation of the job:**

The first step is to prepare a detailed list of all operations in the present method of manufacturing the job. All details such as material handling, machine work and hand work are included in the list. This may be done with the help of a process chart or diagrams of motion and film analysis or models etc.

**Step II: Question each detail of the job:**

Questions should be asked on himself by the motion study engineer about the way in which these operations are to be performed, and about the tools and equipment’s needed. The procedure of this questioning is known as “Critical Examination”.

**Questions are asked on the following five points:**

**i) Purpose:**

What is the purpose of this operation?

Does the operation fulfill the requirements?

Whether the operation can be eliminated?

**ii) Place:**

Where is the best place to do this operation?

**iii) Sequence:**

What is the best time to do this operation?

Whether it can be done at the same time as before or at any other better time?

When will it be more suitable and economical?

**iv) Person:**

Who will do this operation?

Who can do it in a better way?

**v) Means:**

How this operation can be performed i.e. which machines and tools are to be used?

Can we make the work more easier to do and safer for both worker and equipment?

**Step III: Develop a new method:**

After considering the above questions a new better method is developed.

**Before finalising the new method the following facts should also be thought over during the motion study:**

**i) Elimination:**

Every operation of the job should be thought and whether it can be eliminated without any harm.

**ii) Combine:**

In this context it is to be observed that whether two or more can be combined to save operation time.

**iii) Rearrangement:**

If the rearrangement in the sequence of operations helps in simplification or in any other aspect that it should be done.

**For example, in a factory the main sequence of operations was:**

a) Assembling.

b) Storage.

c) Inspection.

d) Despatching.

In this sequence, inspection was carried out before despatching and the defective components were being sent back for correction.

**It can be avoided if inspection is carried out before storage, then the sequence can be rearranged as follows:**

a) Assembling.

b) Inspection.

c) Storage.

d) Despatching.

**iv) Simplification:**

If the operation is possible with any other easy, safe and economical method then that should be adopted.

**The work can be simplified by:**

a) Using material handling equipment.

b) Taking useful work by both hands.

c) Using jigs and fixtures.

d) Placing the materials, tools and equipment at proper working place.

**Step IV: Installing the new method:**

Install the new method as a standard practice.

**For installing the new method, the following procedure is followed:**

i. The new method must get the approval from the supervisors, workers and management.

ii. Then the workers must be trained to work according to the new method.

iii. Observe the installed method until it runs satisfactory.

**Step V: Maintain the new method:**

After implementation, care should be taken to maintain it to avoid unauthorised change in the method.

**For maintaining the new method the following steps are advised:**

a) A job instruction sheet should be given to the worker.

b) Scheduled checks should be done to compare what is actually being done against the job instruction sheet.

c) Selection and training of persons must be done according to the job specifications for this new method.

**Recording Techniques – Charting:**

Recording is the second step in the basic procedure for Method Study. Just after the selection of a particular work for study, the relevant information regarding various processes, inspection, transportation with respect to an existing method or a new method must be recorded properly. Therefore, for efficient recording the charts have been developed.

The recording of the details will be done in charts to get more clear picture. Apart from that a record is also needed before and after comparison is to be made to assess the effectiveness of the study. Charting is the visual representation of recording of facts. It is a technique by which analysis for developing the method can be done quickly and easily.

For easy understanding care should be taken during the time of the preparation of the chart.

**The following details should be given in the chart:**

1. It should possess adequate description of all the activities involved in the method.

2. The current and proposed method should be shown.

3. The specific reference about the beginning and end of the activities should be given.

4. It should depict the time and scale followed.

5. It should explain the abbreviations and devices

6. It should possess the date of preparation of the chart.

**Chapter-5.**

**Statistical Quality Control:**

**The Meaning of Quality and Quality Improvement**

• Quality is conformance to requirements or specifications. – This is the definition used by Crosby who suggests that in order to manage quality adequately, we must be able to quantify and measure it.

• Quality is fitness for use. – This is a more general definition attributed to Juran. It places emphasis on the consumer aspect of quality. It emphasizes that requirements and specifications translate fitness for use into measurable quantities.

• Quality is inversely proportional to variability. – This definition of D. Montgomery (your textbook author) implies that if the variability in a product’s important characteristics decreases, the quality of the product increases. Thus, quality improvement is the reduction of variability in processes and products.

• Quality is the totality of features and characteristics of a product or service that bear on its ability to satisfy given needs. – This definition was the 1978 consensus definition in ANSI/ASQC Standard A3. If you replace the word given with stated or implied you have the ISO definition. – It implies that quality is an attribute of a product. A product is a quality product if it meets all the requirements established for it; that is, it is a defect-free product.

• The quality of a product can be evaluated in many ways referred to as dimensions of quality. Therefore, it is important to differentiate among these dimensions:

1. Performance: Will the product do the intended job?

2. Reliability: How often does the product fail?

 3. Durability: How long does the product last?

4. Serviceability: How easy is it to repair the product?

5. Aesthetics: What does the product look like?

 6. Features: What does the product do?

7. Perceived quality: What is the reputation of the company or its product?

8. Conformance to standards: Is the product made exactly as the designer intended?

 • Quality improvement is the reduction of variability in processes and products. One goal of this course is to learn how to implement statistical tools that can be used to improve quality.

• For every product, the user or consumer defines certain properties of perceived quality referred to as quality characteristics.

• Quality characteristics are often related to specifications. For a manufactured product, specifications define a range of acceptable measurements for the quality characteristics of the product components.

• The desired value for a quality characteristic is called the nominal or target value. A target value is typically bounded by an acceptable interval of values that will not impact the performance of the product if the quality characteristic value is in that range.

• The largest allowable value for a quality characteristics is called the upper specification limit (USL), and the smallest allowable value for a quality characteristics is called the lower specification limit (LSL).

• A quality characteristic may only have one specification limit (USL or LSL, but not both).

• A nonconforming product is a product that fails to meet one or more of its specifications. A specific type of failure is called a nonconformity.

• A nonconforming product is not necessarily unfit for use. For example, a cosmetic nonconformity (like color irregularity) will not effect the fitness of the product for use.

• A nonconforming product is considered defective if it has one or more defects. A defect is a nonconformity that is serious enough to significantly affect the proper usage of the product.

**History and Evolution of Quality Control** **and Improvement (Supplemental)**

 • The need for inspection of manufactured products has been around as long as processes and factories that generate these products have existed. Before industrialization, individual workers or artisans inspected their own work.

• Industrialization made goods available to the masses, but introduced a basic change in commerce by separating the workers who made products from the customers who received them. This depersonalization introduces the need for producers to develop new means to monitor and control the quality of their products.

• Inspectors were now employed to inspect the work of others. Defective products would presumably be found by the inspector and removed or repaired before shipment. Thus, the early focus of quality control was on inspection to identify faulty products and prevent them from being shipped to customers.

• As factories became larger, this burden became too much for the inspector and, consequently, quality control tools and techniques were developed to assist the inspector. Because it was recognized early that variation in measurements is a statistical phenomenon, many of the quality control tools and techniques are statistically based.

• Although the area of experimental design is a major statistical quality method, it will not be included in the following discussion.

**Earliest Developments**

• With the industrial revolution, there were suddenly thousands of unskilled workers involved in high-speed manufacturing operations. Managers usually did not understand the manufacturing process and had little or no experience running large operation. In 1875, Frederick Taylor introduces management principles referred to as “Scientific Management”. – He advocated breaking each process into smaller, more easily completed steps and then have procedures written which detailed how each of these steps should be carried out. Managers should manage the system and workers should do as they are told. – The focus was on productivity. Productivity improved but quality remained a problem. • In the early 1900s, the utilization of the assembly line was pioneered by Henry Ford in the automobile industry. Ford developed automated assembly concepts, self-checking, and inprocess inspection. • Much of the earliest work in quality control was centered in the Bell Telephone System. The need for some methods that could generate confidence in the quality of the system’s instruments was recognized early in the development of this company. Thus, the building of a national communications network created a need for rigorous inspection for assuring the quality of a product being supplied to other companies. • Instead of having each company that receives the products do redundant inspections, the growing AT&T company (in 1907) reorganized and directed the Western Electric Co. to provide inspection and testing for the various Bell Operating Companies under the direction of the Engineering Department of AT&T. This inspection and testing was extended by 1908 to manufactured products, installed products, and purchased materials. • Although very few statistical techniques existed in 1908, sampling was used extensively and efforts were made to judge conformity to requirements and to assess durability and reliability. • By the 1920s, quality assurance was applied to all phases of quality: design, manufacture, and installation. Introduction of the panel switching machine (then a very complex electromechanical device) led to the necessity for a large number of inspectors. The burden was on making the product right with the mantra of “Do it right the first time.” To the current day, many industries have adopted this philosophy to increase productivity and to lower costs. • In 1925, the members of the Inspection Department were transferred to the newly formed Bell Telephone Laboratories. This department contained Walter Shewhart, Harold Dodge, George Edwards, and others. These men were to become the founders of modern quality control methods. As their work proceeded to develop the art and science of inspection engineering, they coined the name Quality Assurance. The department evolved with Edwards as Director of Quality Assurance, Shewhart responsible for theory, and Dodge in charge of methods. • From 1925 to 1941, the development of statistical quality control methodology was remarkable. The concept of monitoring a production process to determine if it was stable over time and capable of producing quality products was introduced. The focus shifted from inspection of a final product to studying the process that is used to make the product. • In JASA (1925), the Shewhart paper “The Application of Statistics as an Aid in Maintaining Quality of a Manufactured Product” introduced the control chart. Within 25 years, the control chart was a basic manufacturing quality control tool used around the world. 6 • Also in 1925, Dodge introduced the basic concepts of sampling inspection by attributes and the concepts of consumer’s risks and producer’s risks. These concepts led to the risks of Type I and Type II errors in the testing of statistical hypotheses.

**Developments in the World War II Era**

• At the beginning of American involvement in WWII, there was an immediate need for large quantities of war materials – everything from guns to radar equipment to shoes. American industry rapidly expanded at the same time as the armed forces expanded. • Many people who had never worked in manufacturing were now employed in those new or expanding factories. Thus, the quality of manufactured goods suffered from lack of skilled personnel. Training programs which emphasized the use of control charts and acceptance sampling plans were then established by companies and government organizations. For example, the War Department engaged Bell Telephone Laboratories to go to manufacturing plants and teach employees simple QC methods. Other instructors were selected from local universities. • In 1940, the War Department published a guide for using control charts to analyze process data. Between 1940-1943, Bell Laboratories developed the forerunners of the military standard sampling plans for the U.S. Army. One of the best-known individuals working with the War Department was Dr. W. Edwards Deming who developed statistical techniques and taught QC courses. • Another development during this period was the establishment of two groups of statisticians and engineers to do research in the use of statistics in quality control. One of these was the Aberdeen Proving Ground in Maryland. This group was formed by Walter Shewhart and included Harold Dodge. Their work resulted in standards for statistical control of quality. • The second group was the Statistical Research Group at Columbia University. Results from this group included the development of sequential analysis and the use of multivariate analysis in quality control with the introduction of the T 2 statistic by Harold Hotelling. • In 1944, the first journal devoted to scientific advances in statistical quality control, Industrial Quality Control, was published. (In 1969, it was replaced by two journals: Quality Progress and Journal of Quality Technology). • At the end of the WWII, groups of faculty and graduate students in the training centers formed local quality control societies. In 1946, many of these societies were combined to form the American Society for Quality Control (ASQC). • Much of the manufacturing capability in Europe and Asia had been destroyed. American manufacturing capabilities, which had grown as part of the war effort, were ready to be converted to peacetime production. There was an insatiable demand worldwide for manufactured products. • Thus, immediately following WWII, the guiding rule was that if you could make it you could sell it. U.S. manufacturers could sell whatever they produced, so the emphasis was now on quantity of production and not on product quality. • Many of the wartime quality lessons were forgotten or ignored, and customers did not seem to care because jobs were plentiful, wages were good, and if something broke, you could always replace it. That is, the U.S. developed into a “throw-away” society: one bought a product and when it failed to perform satisfactorily, threw it away, and bought another. 7 • Postwar Japan faced an entirely different situation. Food and shelter was scarce, and the factories were in ruins. Japan seemed unable to produce manufactured products at a level of quality acceptable to the rest of the world. In short, “Made in Japan” meant junk. • Japan assessed and corrected the causes of their failure. The Japanese Union of Scientists and Engineers took the initiative to deal with this problem that threatened Japan’s economic existence. In 1950, they invited Deming to explain his ideas for quality improvement to leaders of Japanese industry. Dr. Deming had been preaching quality management in the U.S., but no one was listening because everyone was too busy making money. • The Japanese listened to Deming and others (e.g., Juran) and soon mastered the inspection and process control concepts and turned their industries around. In 1951, in his honor, the top Japanese named the individual and plant quality awards the Deming Awards. • The Japanese went on to develop their own quality improvement techniques (e.g. Taguchi and Ishikawa). By the 1970s, they had achieved world leadership in quality.

**Modern Developments**

• One of the earliest techniques developed was the control chart. Its use in Shewhart’s original form is still widespread. When employed this way, it is commonly called a Shewhart chart. • Other control charts have subsequently been developed. These include the cumulative sum (CUSUM) chart and the exponentially weighted moving average (EWMA) chart which use past history in the decision-making procedure. As a result, both charts have the ability of detecting small parameter changes quicker than the Shewhart chart. CUSUM and EWMA charts were introduced, respectively, by E.S. Page in 1954 and S. Roberts in 1959. • Many acceptance sampling standards and procedures were originally developed as military standards by the War Department (United Stated Department of Defense). Although many are still commonly known by their military names, in the U.S. most standards are currently published by the American National Standards Institute (ANSI) and are called voluntary standards. ANSI is responsible for overseeing the quality control standards in the U.S.. • Since WWII, the subject of reliability has developed rapidly. Much of the early work in this field was in the aerospace and electronics industries. From the reliability field, concepts of life testing of products has evolved. This will be discussed later in the course. • One of the earlier ideas (1951), called “Total Quality Control”, was suggested by A.V. Feigenbaum of General Electric. He stressed that responsibility for quality control involved all departments and not just the quality control department. • An outline of the entire scope of managing quality, often called “Total Quality Management (TQM)”, was presented by J.M. Juran. His pioneering work in postwar Japan led to much of Japan’s quality successes. Juran stresses the necessity for leadership by top management, extensive training programs to make basic QC techniques available to every worker, and a dedication to quality at every step: market research, product design, vendor relations, manufacturing, delivery, and service. • Kaoru Ishikawa made significant contributions to Japanese quality. He stated that to achieve company-wide quality control the stress is to be placed on the participation of all in quality control work from the president downward to foremen and operators. 8 • It is interesting to note that many of the pioneers of the quality movement (including Shewhart, Deming, Juran, and Ishikawa) were trained as physical scientists or engineers. Statistical methods provided the tools needed to perform their jobs as scientists or engineers. • In the late 1970s and early 1980s, a number of major changes began to take place in American industry. The automotive sector was in a serious slump and thousands of workers lost their jobs. The ripple effect into other parts of the economy triggered a worldwide recession. It was in this same era that the Japanese quality efforts of 25 years, began to pay off. By the mid-1980s, the balance of trade was the worst it has ever been in the history of the U.S.. • Many U.S. companies then developed quality programs and training courses. Unfortunately, these occurred at the end of the manufacturing process – after the product was manufactured. The R&D (Research and Development) groups were excluded from QC activities. American industries were treating the symptoms but ignoring the root causes for poor quality. • Eventually, many U.S. industries began to adopt Japanese strategies (which were often based on earlier U.S. strategies) to improve product quality. • ISO (International Organization for Standardization) was founded in 1946 to establish a series of international standards for products and production processes. Currently, over 90 countries are members. • In 1987, ISO published the ISO 9000 series of generic standards for quality management and quality assurance. These standards apply to companies of every size and to all industrial sectors – goods, services, and information. Various extensions of the original ISO 9000 standards have been introduced since 1987. • ISO 9000 standards provide guidance for suppliers to implement effective quality systems. They can also be used by customers to evaluate the adequacy of a supplier’s quality system. To avoid the need for each customer to check each supplier, a system of registration was established. ISO audits a supplier and certifies if it is or is not in compliance with ISO standards. Registration gives the customer an assurance that the supplier will provide quality products. • In 1988, the Malcolm Baldridge National Quality Award was established by the U.S. Congress. • More recently, the focus of quality expanded beyond production industries to service industries (which deal with the performance of labor for the benefit of another). Thus, greater emphasis is placed on human factors and their impact on service quality. Examples: food services, health care, building services, transportation, education, finance, and government. • In 1997, many companies begin to adopt Motorola six-sigma approach to quality.

**Management Aspects of Quality Control** :

**Quality Planning** • Quality planning is the development of strategic activities designed to improve the quality of a product. The planning will include both statistical and management activities.

**Quality Assurance** • Another term related to an overall approach to quality control is quality assurance. It is designed to include checks and controls on the quality control procedures in use. – For a specific product or service, this may involve verification audits and the evolution of the quality factors that affect the specification, design, production, procurement, installation, test and inspection, sales, marketing, and use of the product or service. – Quality assurance makes sure that quality control is doing what it should be doing. Such an effort should be organized within a factory, company, or corporation and motivated by management. • Quality Assurance is a system of activities whose purpose is to provide an assurance that the overall quality control is in fact being done effectively.

**Quality Control** • Quality control is the regulatory process through which we measure actual quality performance. – This is the definition given by Juran (1974). It puts quality into an action mode that makes use of standards and measurements. • Quality control: The operational techniques and the activities which sustain a quality of product or service that will satisfy given needs; also the use of such techniques and activities. – This is the ANSI/ASQC Standard A3 definition (1978). • The Statistical Control of Quality is application of statistical principles and techniques in all stages of design, production, maintenance and service, directed toward the economic satisfaction of demand. – This definition was given by Deming (1971) emphasizes the statistical applications, and it also makes explicit the economic objectives of quality control. • Statistical process control (SPC) can be considered as statistical quality control applied to a process or to a product resulting from a process. The DuPont Co. definition of SPC is: – SPC is the totality of all process activities directed at improving process consistency through detecting changes in measured characteristics, identifying causes of changes, and preventing recurrence of those causes.

**Benefits of Quality Control in Industry** :

• Improving the quality of products. • Increasing the productivity of manufacturing processes. • Reducing manufacturing and corporate costs. • Determining and improving the marketability of products. • Reducing consumer prices of products. • Improving and/or assuring on-time deliveries and availability

**Design Quality vs Manufactured Quality**

• Design quality refers to the quality of those product characteristics that will appeal to potential customers. It takes into account what it will cost to produce the product and what the customers are willing to pay for the product. It can be considered as the potential for achieving manufactured quality. • After the manufacturing process has begun, the process does not always produce a unit in conformity with the design. For example, defects arise in materials, parts, subassemblies, assemblies, and in the final product. When these defects are not related to the design, but are related to an inadequate, poorly planned, poorly controlled manufacturing process, we are concerned with manufactured quality (which is also known as the ‘quality of conformance to design’). • Any defective or nonconforming materials, parts, assemblies, and finished products that are discarded or reworked during the manufacturing process result in increased cost and customer dissatisfaction. The lost time and effort in producing the defective or nonconforming product, the loss of business resulting from delays in delivery, and other associated costs attributable to a poorly manufactured product are the consequence of manufactured quality. • Higher design quality usually means higher cost, but higher manufactured quality usually means lower cost. Because the goal should be to provide good quality at low cost, both aspects of quality need to be considered simultaneously. • At the corporate level, insufficient preproduction testing or design qualification may result in the necessity to recall (e.g. automobiles, food products) and repair or replace the product. Thus, quality is also part of corporate attitude. • Understanding of quality concepts contributes to correct implementation and management of product quality, and the entire production enterprise benefits. A manufacturer must be aware of the physical, cultural, and operational environment in which the product will be used. • If quality is understood, great reductions in cost may be possible.

**The Deming Philosophy** • W. Edwards Deming is the most recognized name in quality management. His believed that the primary responsibility for quality lies with management. He often stated that most of quality-related problems can only be solved by management and not the workforce. This is the key to the Deming philosophy. The following summarizes his recommendations to management (known as Deming’s 14 points for management). 1. Create a constancy of purpose toward improvement of products and services with the aim to become competitive, stay in business, and to provide jobs. This can only be achieved if requisite resources and effort are devoted to this end. 2. Adopt the new philosophy. That is, a company should reject old beliefs about quality that some defectives, poor workmanship, and service are to be tolerated. The company must sincerely strive to put quality as a prime objective. 3. Cease dependence on inspection to achieve quality. Eliminate the need for mass inspection by building quality into the product in the first place. Wherever possible, seek to replace inspection for defects with statistical process control methods for prevention of defects. 4. Vendors should be chosen based of ability to supply quality products, and not solely on ability to supply low-cost products. Eliminate the practice of giving contracts to the lowest bidder without regard to quality. Take advantage of building long-term supplier relationships. 5. Seek continuous improvement everywhere to improve quality and productivity, and thus constantly decrease costs. Continuous improvement is to be sought in all the company’s activities, from marketing, accounting, and manufacturing to payroll, engineering, and procurement. 6. Institute training on the job. Train the workforce in the tools, both statistical and nonstatistical, that are needed to improve quality. 7. Improve supervision, empower workers to make decisions about a process, and require management to make necessary process changes and exhibit leadership in quality improvement. The aim of supervision should be to help people and technology to do a better job. 8. Eliminate employees’ fear of asking questions about processes and procedures so that everyone may work effectively for the company. 9. Break down barriers between departments. Departments should become familiar with one another’s operations and take advantage of this knowledge to improve products and processes. 10. Numerical goals, productivity targets, quality targets, and so on should be eliminated. Instead, emphasize continuous improvement. Stressing targets will not increase quality, but stressing quality will achieve such goals. Stressing targets often creates adversarial management/workforce relationships because the majority of causes of low quality and low productivity belong to the system, and thus like beyond the power of the workforce. 11. Work standards and quotas are another form of numerical target and should be eliminated. Instead, substitute improvement aids and helpful supervision. 12. Remove barriers that rob the hourly worker of his/her right to pride of workmanship. Give workers the power to control their particular process or operation. Similarly, remove barriers that rob people in management and engineering of their right to pride of workmanship. Eliminate performance reviews and merit systems for promotions and salary. 13. Everyone should be trained in quality techniques. In particular, the quality department (if one exists) is no longer solely in charge of determining quality or using statistical methods. 14. Only top management can create an atmosphere and structure to make these points work. Deming’s philosophy requires great change in management style for many companies. Under his system, managers are required to be leaders and facilitators, not merely authority figures. They must play an active role in changing systems to improve quality, and not play the passive role of creating targets that the workforce is required to meet.

**Juran’s Organizing for Improvement:**

• Joseph Juran was a quality pioneer whose activities paralleled that of Deming. Like Deming, Juran was also invited by the Japanese. He conducted quality control seminars beginning in 1954, and had consistently been at the forefront of quality improvement. • Unlike Deming who emphasizes statistics and the role of management, Juran’s strengths are in the implementation and organization for change. He describes his steps for solving quality problems as a “breakthrough sequence” which are summarized below:

Establish the existence of a problem. That is, present data and arguments that prove to others, especially management, that a problem exists and is worthy of study. 2. Pare down the list of possible projects to the ‘vital few’ whose solution will provide the greatest impact. Pareto charts are used at this stage. 3. Organize for change. Obtain agreement on the project’s aim, obtain necessary permissions and authority, obtain necessary diagnostic skills, establish time horizons, and plan for implementing the solution. 4. Collect and analyze the data. Statistical tools are used at this stage. 5. Ascertain the effect (on people as well as on processes) of proposed changes and try to limit resistance to these changes. 6. Make the changes. 7. Put controls in place to maintain the improvements (referred to as “foolproofing” by Juran). Juran’s breakthrough sequence is more of a problem-solving technique than it is a list of management objectives. From a management viewpoint, Juran (like Deming) subscribes to the view that the majority of quality problems can only be fixed by management and not by the workforce.

**The Six-Sigma Approach:**

• The goal of the six-sigma approach to business improvement is to find and eliminate causes of mistakes or defects in business processes. To achieve this goal, the focus is placed on outputs that are of critical importance to customers resulting (hopefully) in enhanced process performance, improved customer satisfaction, and increased savings and revenues. • Six sigma is strategic approach designed to work across all processes, products, and industries. The principles not only apply to manufacturing and electronics (where it originated at Allied Signal, Motorola, and General Electric), but to any type of business (e.g., banking and financial services, chemicals, pharmaceuticals, utilities, health care, etc.). • While many six sigma tools are not new, the approach and deployment of the tools are unique (especially to those accustomed to using traditional statistical methods). • Six sigma utilizes a standard deviation (sigma) which is a measure of the capability of the process to achieve defect-free performance where a defect is defined as anything that results in customer dissatisfaction. • The ability to produce products and services with only 3.4 defects per million is described as ‘six sigma’ and is considered as world-class performance for many processes. • The six sigma approach combines statistical methodology with quality processes to create a new methodology. This knowledge is applied to process improvement projects with the goal of increasing bottom-line numbers and customer satisfaction. • The following are 3 aspects of the six-sigma method not emphasized in other approaches:

* 1. Integrating the human element of improvement (e.g., bottom line, management leadership, sense of urgency, customer focus, project teams, culture change) and the process elements of improvement (e.g., analysis of process variation, statistical methods, process management).
	2. Focusing on the bottom line. (No six sigma project is approved unless the bottom line impact has been identified.)
	3. Linking improvement tools into an overall approach. (The five-phase improvement process — design, measure, analyze, improve, control (DMAIC) — is the template.) This is reviewed in Chapter 2 of the text.

• From a statistical point of view, consider the properties of the normal distribution in terms of ppm (parts per million) defective. The following table summarizes the expected number of defective items when LSL and USL are set at target ±kσ:

**Specification Limits Percent Inside Specs ppm Defective**

|  |  |  |
| --- | --- | --- |
| Specification Limits | Percent Inside Specs | ppm Defective |
| ±1 sigma | 68.27 | 317300 |
| ±2 sigma | 95.45 | 45500 |
| ±3 sigma | 99.73 | 2700 |
| ±4 sigma | 99.9937 | 63 |
| ±5 sigma | 99.999943 | 0.57 |
| ±6 sigma | 99.9999998 | 0.002 |

At first look, this table seems reasonable for quality performance. However, this corresponds to a single quality characteristic. What happens if a product has multiple quality characteristics and each one has to meet specifications. If the characteristics are independent of each other, and if any one of them is outside of specifications, then the ppm defective will be much higher than the table values.

Example: If a product has n independent components, then the probability all n components meet specifications is .9973n . For n = 100, this would equal .763 which is unacceptably high

To address this problem, Motorola decided to adopt six-sigma quality. That is, they adopted ±6σ limits which is ≈ 2 parts per billion defective. In the case with n = 100 components, the probability that a unit is nondefective is ≈ .999998 or ≈ .2 ppm.

**The DMAIC Process:**

The objective of the design (D) step is to identify opportunities and to verify/validate the potential for improvement. • The objective of the measure (M) step is to evaluate and understand the current state of the process. This includes collecting data on measures of quality. • The objective of the analyze (A) step is to use the data from the measure step to determine cause-and-effect relationships in the process and to understand the different sources of process variability. • The objective of the improve (I) step is to use the results of the measure and analyze steps to determine specific changes to implement to improve the process. • The objective of the control (C) step is to control the improvements made until future improvements can be made. • A detailed discussion of each of these five steps in given in Chapter 2 of the text.

CONTROL CHART

Also called: Shewhart chart, statistical process control chart

The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit, and a lower line for the lower control limit. These lines are determined from historical data. By comparing current data to these lines, you can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation). This versatile [data collection and analysis tool](https://asq.org/quality-resources/data-collection-analysis-tools) can be used by a variety of industries and is considered one of the [seven basic quality tools](https://asq.org/quality-resources/seven-basic-quality-tools).

Control charts for variable data are used in pairs. The top chart monitors the average, or the centering of the distribution of data from the process. The bottom chart monitors the range, or the width of the distribution. If your data were shots in target practice, the average is where the shots are clustering, and the range is how tightly they are clustered. Control charts for attribute data are used singly.

* [When to use a control chart](https://asq.org/quality-resources/control-chart#Use)
* [Basic procedure](https://asq.org/quality-resources/control-chart#Procedure)
* [Create a control chart](https://asq.org/quality-resources/control-chart#Create)
* [Control chart resources](https://asq.org/quality-resources/control-chart#Resources)

## WHEN TO USE A CONTROL CHART

* When controlling ongoing processes by finding and correcting problems as they occur
* When predicting the expected range of outcomes from a process
* When determining whether a process is stable (in statistical control)
* When analyzing patterns of process variation from special causes (non-routine events) or common causes (built into the process)
* When determining whether your quality improvement project should aim to prevent specific problems or to make fundamental changes to the process

## BASIC PROCEDURE

1. Choose the appropriate control chart for your data.
2. Determine the appropriate time period for collecting and plotting data.
3. Collect data, construct your chart and analyze the data.
4. Look for "out-of-control signals" on the control chart. When one is identified, mark it on the chart and investigate the cause. Document how you investigated, what you learned, the cause and how it was corrected.

### Out-of-control signals

* A single point outside the control limits. In Figure 1, point sixteen is above the UCL (upper control limit).
* Two out of three successive points are on the same side of the centerline and farther than 2 σ from it. In Figure 1, point 4 sends that signal.
* Four out of five successive points are on the same side of the centerline and farther than 1 σ from it. In Figure 1, point 11 sends that signal.
* A run of eight in a row are on the same side of the centerline. Or 10 out of 11, 12 out of 14, or 16 out of 20. In Figure 1, point 21 is eighth in a row above the centerline.
* Obvious consistent or persistent patterns that suggest something unusual about your data and your process.
1. Continue to plot data as they are generated. As each new data point is plotted, check for new out-of-control signals.
2. When you start a new control chart, the process may be out of control. If so, the control limits calculated from the first 20 points are conditional limits. When you have at least 20 sequential points from a period when the process is operating in control, recalculate control limits.

|  |  |
| --- | --- |
| *Comparison of univariate and multivariate control data* | Control charts are used to routinely monitor quality. Depending on the number of process characteristics to be monitored, there are two basic types of control charts. The first, referred to as a univariate control chart, is a graphical display (chart) of one quality characteristic. The second, referred to as a multivariate control chart, is a graphical display of a statistic that summarizes or represents more than one quality characteristic. |
| *Characteristics of control charts* | If a single quality characteristic has been measured or computed from a sample, the control chart shows the value of the quality characteristic versus the sample number or versus time. In general, the chart contains a center line that represents the mean value for the in-control process. Two other horizontal lines, called the upper control limit (*UCL*) and the lower control limit (*LCL*), are also shown on the chart. These control limits are chosen so that almost all of the data points will fall within these limits as long as the process remains in-control. The figure below illustrates this. |



|  |  |
| --- | --- |
| *Why control charts "work"* | The control limits as pictured in the graph might be 0.001 *probability* limits. If so, and if chance causes alone were present, the probability of a point falling above the upper limit would be one out of a thousand, and similarly, a point falling below the lower limit would be one out of a thousand. We would be searching for an assignable cause if a point would fall outside these limits. Where we put these limits will determine the risk of undertaking such a search when in reality there is no assignable cause for variation.Since two out of a thousand is a very small risk, the 0.001 limits may be said to give practical assurances that, if a point falls outside these limits, the variation was caused be an assignable cause. It must be noted that two out of one thousand is a purely arbitrary number. There is no reason why it could not have been set to one out a hundred or even larger. The decision would depend on the amount of risk the management of the quality control program is willing to take. In general (in the world of quality control) it is customary to use limits that approximate the 0.002 standard.Letting *X* denote the value of a process characteristic, if the system of chance causes generates a variation in *X* that follows the normal distribution, the 0.001 probability limits will be very close to the 3*σ* limits. From normal tables we glean that the 3*σ* in one direction is 0.00135, or in both directions 0.0027. For normal distributions, therefore, the 3*σ* limits are the practical equivalent of 0.001 probability limits. |
| *Plus or minus "3 sigma" limits are typical* | In the U.S., whether *X* is normally distributed or not, it is an acceptable practice to base the control limits upon a multiple of the standard deviation. Usually this multiple is 3 and thus the limits are called 3-sigma limits. This term is used whether the standard deviation is the universe or population parameter, or some estimate thereof, or simply a "standard value" for control chart purposes. It should be inferred from the context what standard deviation is involved. (Note that in the U.K., statisticians generally prefer to adhere to probability limits.)If the underlying distribution is skewed, say in the positive direction, the 3-sigma limit will fall short of the upper 0.001 limit, while the lower 3-sigma limit will fall below the 0.001 limit. This situation means that the risk of looking for assignable causes of positive variation when none exists will be greater than one out of a thousand. But the risk of searching for an assignable cause of negative variation, when none exists, will be reduced. The net result, however, will be an increase in the risk of a chance variation beyond the control limits. How much this risk will be increased will depend on the degree of skewness.If variation in quality follows a Poisson distribution, for example, for which *np* = 0.8, the risk of exceeding the upper limit by chance would be raised by the use of 3-sigma limits from 0.001 to 0.009 and the lower limit reduces from 0.001 to 0. For a Poisson distribution the mean and variance both equal *np*. Hence the upper 3-sigma limit is 0.8 + 3 *sqrt*(0.8) = 3.48 and the lower limit is 0 (here *sqrt* denotes "square root"). For *np* = 0.8 the probability of getting more than 3 successes is 0.009. |
| *Strategies for dealing with out-of-control findings* | If a data point falls outside the control limits, we assume that the process is probably out of control and that an investigation is warranted to find and eliminate the cause or causes.Does this mean that when all points fall within the limits, the process is in control? Not necessarily. If the plot looks non-random, that is, if the points exhibit some form of systematic behavior, there is still something wrong. For example, if the first 25 of 30 points fall above the center line and the last 5 fall below the center line, we would wish to know why this is so. Statistical methods to detect sequences or nonrandom patterns can be applied to the interpretation of control charts. To be sure, "in control" implies that all points are between the control limits and they form a random pattern. |