Since the desired α is 5% and β is 10%, plan 1 and 2 come closest to the desired sampling plan.

I TOTAL QUALITY MANAGEMENT

Total Quality Management (TQM) is a major recent development in production and operations management. Though practiced in 1980s, TQM became truly pervasive in the 1990s. Many firms are now adopting a total quality management approach to their business. Under this approach, the entire organisation from the president or chief executive officer down to the lowest level employee are committed and involved in never-ending quest to improve the quality of outputs (continuous improvement or Kaizen in Japanese language). Key elements of TQM include top management commitment, customer involvement and focus, employee involvement and focus, leadership and strategic planning, company wide quality culture, continuous improvement and customer satisfaction and customer delight. However, before discussing about Total Quality Management some fundamental concepts of quality and quality management are discussed in the following paragraphs.

Total Quality Management (TQM): A philosophy that involves everyone in an organisation in a continual effort to improve quality and achieve customer satisfaction.

What is Quality?

Quality is:

- Conformance to specifications.
- Conformance to requirements.
- What the customer thinks it is.
- Measure of the conformance of the product/service to the customer's needs.
- Combination of aesthetics, features and design.
- Value for money.
- The ability of a product to meet customer's needs.
- Meeting or exceeding customer requirements now and in the future.
- Fitness for use of a product/service by the intended customer.
- A customer's perception of the degree to which the product/service meets his/her expectations.
- Totality of features and characteristics of a product/service that bears on its ability to satisfy a stated or implied need.

New Thinking About Quality

Old Quality is "small q"	New Quality is "Big Q"
About products	About organisations
Technical	Strategic
For inspectors	For everyone
Led by experts	Led by Management
High grade	The appropriate grade
About control	About improvement

Eight Dimensions of Product Quality

1. Performance 2. Features 3. Reliability 4. Serviceability 5. Aesthetics (appearance) 6. Durability 7. Customer service 8. Safety

Ten Dimensions of Service Quality

1. Reliability 2. Responsiveness 3. Competence 4. Access 5. Courtesy 6. Communication 7. Credibility 8. Understanding 9. Security/Safety 10. Tangibles.

Benefits of Quality

1. Gives positive company image.
2. Improves competitive ability.
3. Increases market share and net profits.
4. Reduces costs.
5. Reduces product liability problems.
6. Improves employee morale.
7. Improves productivity.

Customer–Driven Definitions of Quality

1. Conformance to specifications (requirements).
2. Value for money
3. Fitness for use.
4. Support provided by seller (customer services)
5. Psychological impression (image, aesthetics)

Perceived Quality : "An assessment of quality based on the reputation of the firm." Customers base their assessment of quality on such factors as advertisements, media reports, reputations and past experience to indicate perceived quality.

Customer–Driven Quality : Quality is meeting or exceeding customer expectations. The term "customer" includes both the "internal customer" and the "external customer" in the "customer chain".

Three Levels of Quality

1. Organisation level	–	Meeting external customer requirements
2. Process level	–	Meeting the needs of internal customers
3. Performer level (job level or task design level)	–	Meeting the requirements of accuracy, completeness innovation, timeliness and cost.

Determinants of Quality

1. Quality of design, 2. Quality capability of process, 3. Quality of conformance, 4. Quality of customer service, 5. Organisation quality culture.

QUALITY IS	**Q**	–	Quest for excellence
	U	–	Understanding customer needs
	A	–	Action to achieve customer satisfaction
	L	–	Leadership – determination to be a leader
	I	–	Involvement of all people
	T	–	Team spirit to work for common goals
	Y	–	Yardstick to measure progress.

I WHAT IS QUALITY MANAGEMENT?

Inspection to ensure quality (in early 1900s)

Statistical quality control (in the 1940s)

Total quality management: including the entire organisation (1960's onwards)

Nowadays Total Quality Management (TQM) means :

- Top Management Commitment to quality
- Customer involvement and focus
- Employee involvement and focus
- Leadership and strategic planning for quality
- Company-wide quality culture
- Continuous improvement
- Customer satisfaction and delight

TQM improves productivity and competitive advantage.

What is Quality Control?

1. Setting quality standards (objectives or targets)
2. Appraisal of conformance (quality measurement)
3. Taking corrective actions to reduce deviations
4. Planning for quality improvement

Quality control begins with product design and includes materials, bought-out items, manufacturing processes and finished goods at the hands of customers.

Quality control aims at prevention of defects rather than detection of defects (by inspection)

Objectives of quality control is to provide products/services which are dependable, satisfactory and economical.

Quality & Reliability : Reliability is the probability of performing without failure, a specified function under given conditions for a specified period of time.

Company-Wide Quality Control (CWQC) : System of activities that assume that quality products and services required by customers are economically designed, produced, and supplied involving all departments of an organisation

Quality Assurance : All activities required to ensure that the product performs to the customers' satisfaction

Quality Improvement : Finding ways to do better than standard and breaking-through to unprecedented levels of performance. It is the responsibility of those who produce the products and not of inspectors. (*i.e.*, quality at the source)

Concept of Total Quality : Systems approach to quality. Involves all employees (top to bottom) and extends backward to forward (*i.e.*, supply chain & customer chain). Total quality stresses learning and adaptation to continual change as key to organisational success. It includes systems, methods and tools.

Principles of Total Quality

- Focus on the customer (Both internal & external)
- Participation and Team work
- Employee involvement and empowerment
- Continuous improvement and learning.

What is Total Quality Control (TQC)?

It is quality control and improvement from **shop floors** to **board rooms**. It is an effective system for **integrating quality development**, **quality maintenance** and **quality improvement** efforts of **various groups in an organisations**.

Principles of Total Quality Control (TQC)

1. Top management policies – Zero defects, continuous improvement etc.
2. Quality control training for everyone
3. Quality at product/service design stage
4. Quality materials from suppliers
5. Quality control in production (SQC)
6. Quality control in distribution, installation and use.

What is Total Quality Management (TQM)?

A **philosophy** that **involves everyone** in an organisation in a **continual effort** to **improve quality** and achieve **customer satisfaction**.

Six Basic Concepts in TQM

1. Top management commitment and support.
2. Focus on both internal and external customers.
3. Employee involvement and empowerment.
4. Continuous improvement (KAIZEN)
5. Partnership with suppliers
6. Establishing performance measures for processes.

8 Essentials of TQM Focus

1. Customer satisfaction
2. Leadership
3. Quality policy
4. Organisation structure
5. Employee involvement
6. Quality costs
7. Supplier selection and development
8. Recognition and reward.

Seven Underlying Principles in TQM

1. Strive for **quality** in **all things** (Total Quality)
2. The **customer** is the **creation** of **quality**
3. **Improve** the **process** or **systems** by which products are produced
4. **Quality improvement** is **continuous**, never ending activity (continuous improvement-Kaizen)
5. **Worker involvement** is essential
6. Ground decisions and actions on **knowledge**
7. Encourage **team work** and **cooperation**.

Scope of TQM

1. Are integrated **organisational infrastructure**
2. A set of **management practices**
3. A wide variety of **tools** and **techniques**

I MODERN QUALITY MANAGEMENT

Quality Gurus and their Philosophies

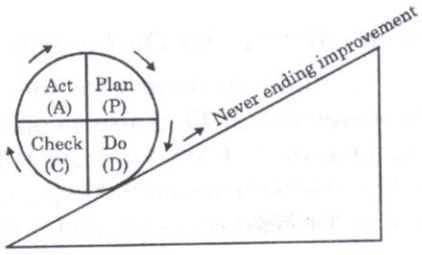
1. **W. Edwards Deming(USA)** [U.S. statistician & consultant known as father of quality control]
   - *(a)* Higher quality means lower cost
   - *(b)* Quality means continuous improvement
   - *(c)* 14 points for quality management
   - *(d)* Seven deadly diseases and sins
   - *(e)* Deming wheel/cycle (P–D–C–A cycle)
   - *(f)* Deming's triangle
   - *(g)* Deming prize.

Deming's 14 Points for Quality Management

1. Create constancy of purpose for continual improvement of product/services.
2. Adopt the new policy for economic stability.
3. Cease dependency on inspection to achieve quality.
4. End the practice of awarding business on price tag alone.
5. Improve constantly and forever the system of production and service.
6. Institute training on the job.
7. Adopt and institute modern method of supervision and leadership.
8. Drive out fear. (Fear of failure, fear of change etc).
9. Breakdown barriers between departments and individuals.
10. Eliminate the use of slogans, posters and exhortations.
11. Eliminate work standards and numerical quotas.
12. Remove barriers that rob the hourly worker of the right to pride in workmanship.
13. Institute a vigorous program of education and retraining.
14. Define top management's permanent commitment to ever improving quality and productivity.

Deming's Seven Deadly Diseases and Sins

1. Lack of constancy of purpose (short-term quality programs)
2. Emphasis on short-term profits
3. Over reliance on performance appraisals
4. Mobility of management (Job hopping)
5. Over emphasis on visual figures
6. Excessive medical costs for employes healthcare
7. Excessive costs of warranty and legal costs.



Deming Wheel/Deming Cycle/P–D–C–A Cycle

P – Plan (process) **the improvement**

D – **Do** Implement the plan

C – **Check** – Check how closely result meets goals

A – **Act** – Use the improved process as standard practice

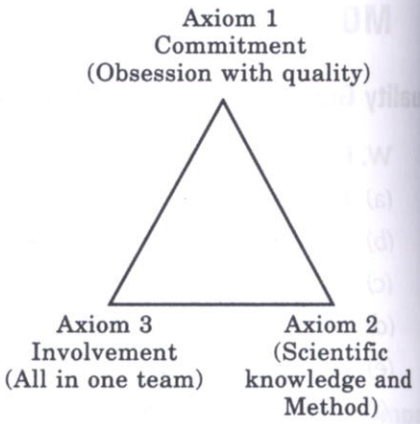
Deming's Triangle (3 Axioms)

Axiom 1 : **Commitment** (Obsession with quality)

Axiom 2 : (**Scientific Knowledge** & Method)

Axiom 3 : **Involvement** (All in one team)

Deming Prize : Awarded by the union of Japanese Scientists and Engineers (JUSE) to a firm or its division based on the distinctive performance improvements achieved through the application of Company Wide Quality Control (CWQC).



2. Joseph Juran (USA)

(Professor and Quality consultant – wrote 12 books on quality including Quality Control Hand Book) Defined quality as "fitness for use".

Philosophy :

(a) Top management commitment, *(b)* Costs of quality, *(c)* Quality triology, *(d)* 10 steps for quality improvement, *(e)* Universal breakthrough sequence.

Costs of Quality

1. **Prevention costs :** Costs of quality planning, new product review, training, process planning, quality data and improvement projects.
2. **Appraisal costs :** Costs of incoming inspection, process inspection, finished goods inspection, quality laboratories and calibration of instruments.
3. **Internal failure costs :** Costs of scrap, rework, down grading (seconds quality products) retest, downtime.
4. **External failure costs :** Costs of warranty, returned goods, customer complaints, allowances to customers for substandard quality products.

Costs of quality can be reduced by revising the production system including technology, management, attitudes and training.

Quality Triology

(i) Quality planning, *(ii)* Quality control and *(iii)* Quality improvement.

Quality Habit

1. Establish specific goals
2. Establish plans for achieving these goals
3. Assign clear responsibilities to employees
4. Base rewards on results.

Juran's 10 Steps for Quality Improvement

1. Build awareness for the need and opportunity for improvement 2. Set goals for improvement 3. Organise people to reach the goals 4. Provide training throughout the organisation 5. Carryout projects to solve problems 6. Report progress 7. Give recognition 8. Communicate results 9. Keep score 10. Maintain momentum by making annual improvement part of the regular system and processes of the company.

Universal Breakthrough Sequence

Break-through or major improvements follow the 7 steps given below:

1. Proof of need 2. Project identification 3. Organising for improvements 4. Diagnostic journey 5. Remedial action 6. Resistance to change 7. Holding on to gains.

3. Philip B Crosby (USA)

(Management consultant and director of Crosby's Quality College. Wrote a book titled "Quality is free" of which 1 million copies sold)

Philosophies

(a) Quality is free *(b)* Goal of zero defects *(c)* 6 'C's – Comprehension, Commitment, Competence, Correction, Communication, Continuance. *(d)* Four absolutes of Quality *(e)* 14 steps for quality improvement *(f)* Quality Vaccine/Crosby Triangle.

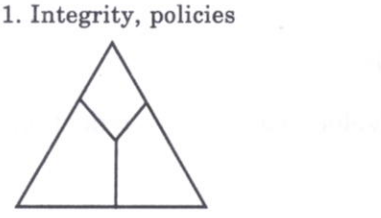
4. Absolute of Quality

1. Quality is defined as conformance to requirements, not goodness.
2. The system for achieving quality is prevention, not appraisal.
3. The performance standard is zero defects not that is close enough.
4. The measurement of quality is the price of non-conformances, not indexes.

Crosby's 14 Steps for Quality Management

(i) Management commitment *(ii)* Quality improvement team *(iii)* Quality measurement *(iv)* Cost of quality *(v)* Quality awareness *(vi)* Corrective action *(vii)* Zero defects planning *(viii)* Supervisor training *(ix)* Zero defects day *(x)* Goal setting *(xi)* Error cause removal *(xii)* Recognition *(xiii)* Quality councils *(xiv)* Do it all over again.

Crosby's Quality Vaccine or Crosby Triangle



5. Armand V. Feigenbaum (USA)

(i) Concept of TQC (Total Quality COntrol)

(ii) Quality at the source

(iii) Three steps to quality – Quality leadership, Modern quality technology, Organisational Commitment.

(iv) SQC and CWQC (Company-Wide Quality Control)

6. Kaoru Ishikawa (Japan) (Japanese Quality Authority)

(i) Quality circles *(ii)* Ishikawa diagram for problem solving *(iii)* Quality training *(iv)* Root cause elimination *(v)* Total employee involvement *(vi)* Customer focus *(vii)* Elimination of inspection *(viii)* C.W.Q.C. *(ix)* Japanese quality strategy.

7. Genichi Taguchi (Japan)

(i) Quality Engineering *(ii)* Taguchi Methods *(iii)* Taguchi's quality loss function ($L = cd^2$) [L=Loss–C = Constant d = deviation *i.e.*, x – T]

8. **Masaki Imai** (Management Consultant of Japan) – (Continuous improvement)

9. **Shigeo Shingo** (Japan)

"Poka Yoke" – means "Fail proofing" or "Fool-proofing" to reduce defects to zero (Handle errors as they occur)

10. **Dr. Walter Shewhart (USA) :** (Statistician at Bell Laboratories)

Statistical Quality Control : *(a)* SPC control charts *(b)* Acceptance sampling (with Dodge & Romig)

Elements of TQM Concept

1. Sustained top management commitment to quality
2. Focus on Customer requirement and expectations
3. Preventing defects rather than detecting them
4. Recognising that responsibility for quality is universal
5. Quality measurement
6. Continuous improvement (Kaizen) approach
7. Root–cause corrective action
8. Employee involvement and empowerment
9. Synergies of Team work
10. Process improvement (Continuous Improvement – Kaizen, 6 σ – Quality, Break–through Improvement, Reengineering)
11. Thinking statistically
12. Bench marking
13. Inventory reduction (JIT)
14. Value improvement (Value analysis, cost reduction) $\left[\text{Value} = \frac{\text{Performance}}{\text{Cost}}\right]$
15. Supplier partnership
16. Quality training for all
17. Business process reengineering (Break-through improvement)

Total Quality Management Program

1. **Top management commitment and involvement :** Top management support for TQM – Leadership, strategic quality planning, Organising for quality, Quality training for all, Quality policies and Quality objectives, Human resources for quality, building superior quality into business strategy, Company-wide quality culture, Supplier partnering, employee involvement and empowerment, process improvement and benchmarking and Business process reengineering.
2. **Customer involvement :** Customer focus, knowing what the customer wants - Voice of the customer to be considered while designing the product using QFD approach (*i.e.*, Quality Function Deployment), involving both internal and external customers.
3. **Designing products for quality :** Designing for robustness, designing for production (Producibility or economic production) designing for reliability.
4. **Designing and controlling production processes :** Process capability, six-sigma quality (*i.e.*, 3.4 defects per million opportunities for defects) and zero defects.

5. **Developing supplier partnerships :** Quality at the source, Suppliers as partners not adversaries Supplier development (TQM suppliers, JIT supplies)
6. **Customer service, distribution, installation :** Packing, shipping and installation of products, after sales service, warehousing, marketing and distribution function to be committed to perfect quality.
7. **Building teams of empowered employees :** Employee training, work teams, empowerment, quality at source (worker, not inspector to ensure quality), quality circles, quality improvement teams, management teams etc.
8. **Bench marking and continuous improvement (Kaizen) :** Bench marking is the practices of establishing internal standards of performance by looking at how world-class companies (leaders in the class) run their businesses. The practices of world-class companies become the basis for continuous improvement to achieve excellence in performance.

I PROCESS MANAGEMENT

Process Management involves planning and administering various activities to achieve high level performance in a process and identifying opportunities for improving quality and operational performance and ultimate customer satisfaction.

Process management involves design, control and improvement of key business process.

It involve design, control and improvement of key business processes.

4 category of business processes are:

(i) Design processes – product design (or service design) and design of production/delivery processes that create and deliver products

(ii) Process design (conversion processes)

(iii) Support processes (purchase, stores, quality control, marketing, maintenance, finance etc)

(iv) Supplier processes/partnering process (vendor development)

(Product design and process design processes are known as Core processes)

Process improvement opportunities include:

(i) Reducing manufacturing cycle times and defects

(ii) Improving morale and satisfaction of employees

(iii) Improving managerial practices

(iv) Improving product design to improve quality and reliability.

(v) Eliminating scrap and rework

(vi) Improving the efficiency of manufacturing systems by reducing worker's idle time and wasteful activities.

5 W 2 H Approach to Process Improvement

1. What is being done?
2. Why is this necessary?
3. Where is it being done?
4. When is it done?
5. Who is doing it?
6. How is it being done?
7. How much does it cost now?

Process Improvement Methods

1. Work simplification
2. Planned methods change

Kaizen enhances quality through:

1. Improvement in supplier relations
2. New product planning and development
3. Improvement in employee safety
4. Reduction in cost
5. Meeting delivery schedules
6. Employer skill development

Three Guiding Principles of Kaizen

1. Process view of the system – Analysis of design process & production processes
2. Success comes from people – employee participation and team work
3. Constant sense of urgency – need for change

Activities Falling Under Kaizen Umbrella

1. Customer orientation 2. Total quality control 3. Robotics 4. Advanced technology (NC, CNC machines) 5. Quality circles 6. Automation 7. Discipline in workforce 8. Total productive maintenance 9. Kanban (JIT) 10. Quality improvement 11. Zero defect program 12. Quality improvement teams 13. Co-operation (labour – management relation) 14. New product development 15. Productivity improvement

Break-through Improvement or Stretch Goals

Setting challenging goals in all areas of operations (business processes). Stretch goals force the management to think in a radically different way and encourage both incremental and major improvements.

Two approaches of stretch goals are : 1. Bench Marking 2. Reengineering or Business Process Reengineering.

BENCH MARKING

Bench marketing : Measuring a company's performance against that of best-in-class companies, determining how the best-in-class achieve those performance levels and using the information as a basis for the company's targets, strategies and implementation.

Measuring your performances against that of the best-in-class companies, determining home the best-in-class achieve those performances level and using the information as a basis for your company's targets, strategies and implementation.

3 types of benchmarking are:

1. **Performance benchmarking** – pricing, technical quality, product performance and features and services.
2. **Process bench marking** – work processes such as billing, order entry, employee training etc.
3. **Strategic bench marking** – how firms compete and seek winning strategies that have led to competitive advantage and market success.

Bench Marking Process

1. Decide what to benchmark
2. Select companies to benchmark
3. Obtain data and collect information
4. Analyse data and form action plans
5. Recalibrate and start the process again.

Business Process Reengineering: The fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical contemporary measures of performance such as cost, quality, service and speed.

BUSINESS PROCESS REENGINEERING (BPR)

A fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance such as cost, quality, service and speed to market. It involves basic questions such as :

(i) Why do we do it? *(ii)* Why is it done that way?

Requirements of Successful BPR Process

1. Fundamental understanding of the process.
2. Creative thinking to break away from old traditions and assumptions.
3. Effective use of information technology.

Steps in BPR Process

1. State a case for action (*i.e.,* need for change).
2. Identify the process for reengineering.
3. Evaluate enablers for reengineering (information technology and human resources issues).
4. Understanding the current process.
5. Create a new process design.
6. Implement the reengineered process.

Relationship Between Benchmarking and Reengineering

Reengineering without benchmarking will produce 5 to 10 per cent improvements whereas benchmarking can improve the reengineering to 50 – 70 per cent. More about business process reengineering will be discussed in Chapter 20.

Tools for process management (Problem Solving)

		Q.C.Tools
1. Understanding the problem (or mess finding)	:	Flow charts Run charts Control charts
2. Finding facts	:	Stratification, check sheets
3. Identifying problems	:	Pareto diagram, Histogram
4. Generating ideas (Solutions)	:	Cause-and-effect diagram (Ishikawa or Fishbone diagram)
5. Developing solutions	:	Scatter diagram
6. Implementing the plan	:	Seven management and planning tool (Affinity diagram, Inter relationship diagraph, Tree diagram, Matrix data analysis, Process decision, Progress chart, Arrow diagrams)

7 QC tools are:

1. Stratification
2. Pareto's diagram
3. Check sheet
4. Histogram
5. Cause and effect diagram
6. Control chart
7. Scatter diagram

5 'S'Kaizen movement or Japanese 5 'S' Approach

1. **Seiri** – Straighten-up – Avoid unnecessary materials, tools, machinery, documents etc.
2. **Seiton** – putting things in order – Everything should be in its place and there should be place for everything (good house keeping)
3. **Seiso** – clean-up – Every individual should clean-up his work place everyday after the work.

4. **Seiketsu** – (Personal cleanliness) – Healthy body – healthy mind.
5. **Shitsuke** (discipline) – Every worker & manager has to follow rules and procedures in the work place.

3 'MU's check list (of Kaizen)

1. Muda (Waste)
2. Muri (Strain)
3. Mura (Discrepancy)

QUALITY MOVEMENT IN INDIA

Quality has been a tradition in India and monuments, relics, handicrafts, gems, jewellery and craftsmanship have woven quality into our heritage. But while quality was a way of managing business in the US and Japan in the 1950s, it was not so in India. The Quality Movement was consolidated in the 1980s in the Indian industries to bring about a synergy of resources by the pioneering efforts of Confederation of Indian Industries (CII).

Walter Shewart, the father of statistical quality control, visited India for a short period of three months during 1947-48 and initiated the SQC movement through visits to factories, personal discussions and lectures. Dr. Edward Deming who taught the Japanese the means of applying the Plan-Do-Check-Act cycle (known as Deming Cycle) came to India in the early 1950s. While the Japanese attributed their success to the learnings from two American Gurus, Dr. Deming and Dr. Juran, the rest of the world was lagging behind until the 1970s when the effect began to hurt businesses. The formal launch of TQM movement in the US in the early 1980s triggered a movement for quality in India and in 1982, the quality control circle was born. Among some of the companies launching quality control circles first were public sector undertakings – Bharat Electronics and Bharat Heavy Electricals. A movement also began in Nasik with the umbrella of CII when a small group of companies began to practice some of the quality circle techniques and showed some results. Later, CII provided a focus and an impetus to the quality movement by forming the TQM division in 1987. By then the focus had shifted from Quality Circles to Quality Management. The movement on Quality Circles was consolidated by the Quality Circle Forum in India (QCFI). Prof. Ishikawa, founder of Quality Movement in Japan was invited by CII to come to India to address the Indian Industry in 1986. Also, some companies began to set up "Quality Improvement Teams" for setting the path of continuous improvement. CII organised its first major seminar with Juran in 1987. The mid 80s also began the process of socio-economic reforms, setting a trend for competition and liberalisation. CII set up the TQM division with the help of 21 companies who agreed to support the cause by pooling in resources and pledging to start the journey of TQM. The chief executives of these companies formed the National Committee on Quality, which brought into focus the need to build awareness and the "Quality Month" was declared to be an annual event to reinforce the message and spread it wider each year. CII also launched the first newsletter on Quality.

The year 1987 brought the ISO 9000 standards into reality and visible strategies emerged from the European market to set a global trend towards standardising and certifying Quality Systems. Since, the European Market was a big market for Indian industries, CII organised training courses for ISO 9000 in 1989. Two years later, in 1991, the first company in India got certified to ISO 9000. From there onwards, the movement has gathered momentum and today more than 500 companies have secured ISO 9000 certification. The TQM movement today encompasses not only engineering industries, but also servicing and information technology industries. Today, TQM has become a thrust area in quality movement as it was realised that through ISO 9000 certification alone, companies cannot become world class or competitive. Many chief executives and senior management personnel visited Japan and started serious effort with enthusiasm to

become the market leaders. CII organised domestic study missions to prove the applicability of TQM concepts in India. Sharing experiences, building each other's strengths became essential ingredients towards the Indianisation of the TQM concepts as accepted universally. CII developed through application research a set of nine modules for training on TQM.

CII worked with the Government of India to initiate a drive to create an awareness on quality and customer orientation in State and Central Government Departments, Financial Institutions and Banks, Indian Railways, Textile Corporations, Leather Institutions and Educational Institutions including IITs and IIMs. Also, "National Quality Council for India" was promoted and integrated into an overall thrust for a National Movement. CII organised the launch of a National Quality Campaign in 1992, led by the Prime Minister of India and the "Quality Summit" organised by CII has now become an annual feature across the country.

The companies practicing TQM have implemented some common features such as "people movement" (through quality control circles, quality improvement teams, suggestion schemes, Kaizen and JIT), Quality Assurance Systems (ISO 9000), Vendor Development, Statistical Process Control and other tools and techniques such as Quality Function Deployment, Reliability and Design of Experiments.

The future thrust of the quality movement in India would be in the following areas:

(i) Application Research where we need to understand the relationship of what has to be done with the context in which it need to be done. This requires a depth of the understanding and will be possible through synergy of industry and academics.

(ii) Grooming of facilitators through local people being trained as facilitators of TQM/ISO 9000 in every organisation willing to implement TQM.

(iii) Experience sharing to understand the means to get organisational performance through TQM.

(iv) ISO 9000 certification for small scale industries who are exporters or potential exporters.

(v) Environmental protection, safety and consumer protection by the industrial organisations through highly focussed effort on quality enhancement.

QUALITY CIRCLES (QC)

It was quality circles which gave birth to TQM. A *quality circle* is a group of employees whose assignment is to identify problems, formulate solutions, and present their results to management with suggestions for implementation.

Quality circle: A small group of employees who meet regularly to undertake work-related projects designed to improve working conditions, spur mutual self-development and to advance the company, all by using quality control concepts.

The definition given by the Union of Japanese Scientists and Engineers (JUSE) is more revealing. To quote the definition: *"the QC is a small group that voluntarily performs quality control activities within the shop, where its members work, the small group carrying out its work continuously as part of a company-wide programme of quality control, self development, mutual development and flow-control and improvement within workshop. By engaging in QC activities, the circle members gain valuable experience in communication with colleagues, working together to solve problems, and sharing their findings, not only among themselves but with other circles at other companies."*

As in TQM, popular perception about QC is that, it deals with only product quality. Far from it, QC also aims at individual and group development. In other words, QC has quality of life as its primary objective. But in reality, QC is perceived to be an instrument to achieve high product quality.

Although simple in concept, successful implementation of quality circles programme requires a massive effort on the part of management. The support structure usually consists of a steering committee of top management officials, facilitators, circle leaders, and circle members.

Steering Committee : Provide overall guidance, suggest problems for the circles to address, receive recommendations from the circles, and follow up on implementation. The steering committee must make sure that, the circles receive the support they need, to be effective.

Facilitators : One facilitator is assigned to several circles. They provide training for the leaders and support the training programmes for the members. When the circle requests information, the facilitator's responsibility is to provide it. A facilitator must be well connected in the organisation and requires strong backing from top management.

Circle Leaders : Often an area supervisor, a leader has responsibilities that include training the circle members in problem identification and solution methods, and preparing an effective presentation to management. This is considered as an excellent preparation for someone, who is likely to be promoted, since they become indoctrinated in the philosophy that a manager's function is to facilitate the tasks of the workers.

Circle Members : These are volunteers from the regular work force. They are given one hour of company time weekly to carry out their discussion and projects. Trained in techniques of brain-storming and identifying causes, they keep the facilitator busy by requesting information about various problems of their choice. Based on preliminary findings, the group focuses on a problem and works out a solution and a strategy to implement it. If the recommendation is accepted by the steering committee, the circle is kept posted on its progress. If the recommendation is rejected, it is the responsibility of the steering committee to explain in detail why it was rejected.

Started first in Japan, quality circles have grown in number everywhere in the world. In Japan, there are more than 170,000 QCs officially registered with JUSE and probably twice that many operating independently of JUSE. Since the typical circle has six to ten members, it is estimated that there are at least three million workers in Japan directly involved in some kind of official QC activity.

The QC activities are interconnected in a nationwide network, and QC members have easy access to what other people are doing in other industries. There are more than 1,000 volunteer QC leaders in Japan co-operating in organising local and national meetings to promote the flow of information among members.

Elsewhere, companies like J.C. Penny and Co., US Navy, Armstrong Cork, GE Co., Ford, Firestone, Bendix Corporation, Victor Business Machines, General Motors and Lockheed, have employed QC approach in their respective plants.

In India, BHEL, BEL, BFW, Shriram Fibres Ltd., ECI, Durgapur Steel Plant, Kirloskar Electric Co., L&T, HMT, TELCO, Hindustan Antibiotics Ltd., and Essar Industries have QCs in their respective organisation.

QUALITY CERTIFICATION

Though total quality management (TQM) was practiced by many firms in the 1980s, TQM became truly pervasive in the 1990s. Production and operations executives and managers started applying the quality philosophies putforth by the so-called quality gurus – W Edwards Deming, Joseph M. Juran and Philip Crosby in the firms in the US. The quality movement was augmented with the institution of Malcom Baldrige National Quality Award in 1986 under the direction of American Society of Quality Control and the National Institute of standards and Technology. The Baldrige Award recognises upto five companies a year for outsanding **quality management systems.**

The ISO 9000 certification standards putforth by the International Organisation for Standardisation now play a major role in setting quality standards for global manufacturers in

particular. Many European companies require that their vendors meet these standards as a condition for obtaining supply contracts.

Quality Systems

A **quality system** is defined as *"The collective plans, activities and events that are provided to ensure that a product, process or service will satisfy given needs".*

The systems approach to quality integrates the various functions and responsibilities of different units and provides a mechanism to ensure that organisational goals are being met through the coordination of goals of the individual units. Effective quality control requires the integration of quality actions of the people, the machines and the information into strong total quality systems.

ISO 9000

ISO 9000: A set of international standards on quality management and quality assurance, critical to international business.

As quality became a major focus of business throughout the world, various organisations developed standards and guidelines. Terms such as quality management, quality control, quality system and quality assurance acquired different meanings in different countries, within a country and even within an industry. As the European community moved towards the European Free Trade Agreement which went into effect at the end of 1992, quality management became a key strategic objective. To standardise quality requirement of European countries within the common market and those wishing to do business with those countries, a specialised agency for standardisation, the *International Organisation for Standardisation (IOS)* was founded in 1946 and composed of representatives from the national standards bodies of 91 nations. It adopted a series of written quality standards in 1987. These are called the ISO 9000 standards and were revised in 1994. The IOS adopted the ISO prefix in naming the standards.

'ISO' means equal (Isotherm lines of a weather map show equal temperatures). Organisations certified under the ISO 9000 standard are assured to have quality equal to their peer organisations. The standards have been adopted in the US as the ANSI/ASQC Q9000 – 1994 series but are commonly referred to as ISO 9000. The standards are recognised by over 100 countries including India and Japan. In some foreign markets, companies will not buy from non-certified suppliers. Thus, meeting ISO 9000 standards is becoming a necessity for international competitiveness. The standards are applicable to all types of manufacturing and service industries. ISO 9000 certification assures customers that a firm has designed and managed its processes to assure delivery of a quality product.

ISO 14000: A set of international standards for assessing a company's environmental performance.

The texts of these standards released by the ISO central secretariat in Geneva are adapted as the IS 14000 series of standards by the Bureau of Indian Standards (BIS). These standards embody comprehensive quality management concepts and guidance. The control (creation, modification and deletion) of all documents related to quality management is an important requirement of ISO 9000 covering elements such as drawings, specifications, blueprints, work instructions, test procedures, inspection reports, calibration data and quality cost reports. A record retention system should be in place to facilitate the use of these documents, which are themselves organised in three tiers – *(i)* the quality manual *(ii)* the work procedures and *(iii)* the instructions and data records.

The ISO 9000 standards require that third party audits be performed leading to the suppliers becoming certified. This certification is accepted by all customers, eliminating 10 to 20 different audits by many companies interested in doing business with a supplier.

Perspectives on ISO 9000

Many misconceptions exist about what ISO 9000 actually is. The standards do not specify any measure of quality performance and specific quality levels are set by the company. The standards only require that the suppliers have a verifiable process in place to ensure that it

consistently produces what it says it will produce, thus providing confidence to customer and the company management that certain principles of good management are followed. The standards emphasise documenting conformance of quality systems to the company's quality manual and established quality system requirements. The philosophy of ISO 9000 standard is – "Document it and do it like you document it. If it moves, train it. If not, calibrate it." A supplier can comply with the standards and still produce a poor quality product – as long as it does so consistently!

In addition, ISO 9000 does not consider activities such as leadership, strategic planning or customer relationship management.

Environmental Aspects in Product Standards

This section is a guide for standards writers. Its purpose is to incorporate environmental training into the development of product standards to prevent adverse impacts on the environment. The development and the drive behind ISO-14000 has been strongly influenced by the British Standard BS 7750, the European Communities' Eco-Management and Audit Scheme (EMAS), the Chemical Industry Responsible Care, the International Chamber of Commerce (ICC), the Global Environmental Management Institute (GEMI), the Coalition for Environmentally Responsible Economies (CERES) and particularly the ISO 9000 Quality Standards.

ISO 9001 : 2000

The Indian standard (second revision) which is identical with ISO 9001 : 2000 "Quality Management Systems – Requirements" issued by International organisation for standardisation (ISO) was adopted by the Bureau of Indian Standards (BIS) on the recommendation of the Quality Management Sectional Committee and approval of the Management and Systems Division Council.

This second revision of IS/ISO 9001 cancels and replaces the first revision (IS/ISO 9001 : 1994) together with IS/ISO 9002: 1994 and IS/ISO 9003 : 1994. It constitutes a technical revision of these documents.

The title of IS/ISO 9001 has been revised in this edition and no longer includes the term "Quality Assurance" This reflects the fact that the quality management system requirements specialised in this edition of IS/ISO 9001, in addition to quality assurance of a product, also aim to enhance customer satisfaction.

Scope of IS/ISO 9001 : 2000

This international standard specifies requirements of a quality management system where an organisation.

(a) needs to demonstrate its ability to consistently provide products that meet customer and applicable regulatory requirements.

(b) aims to enhance customer satisfaction through the effective application of the system including processes for continued improvement of the system and the assurance of conformity to customer and applicable regulatory requirements.

Application

All requirements of this International standard are generic and are intended to be applicable to all organisations regardless of type, size and product provided.

Process Approach

ISO 9001 : 2000 promotes the adoption of a process approach when developing, implementing and improving the effectiveness of a quality management system, to enhance customer satisfaction by meeting customer requirements.

The application of a system of processes within an organisation together with the identification and interactions of these processes and their management, can be referred to as the "process approach".

The various aspects covered by ISO 9001 : 2000 are :

1. Scope - general and application, 2. Normative reference, 3. Terms and definitions, 4. Quality management system – general requirements, documentation requirements (quality manual, control of documents, control of records), 5. Management responsibility – management commitment, customer focus, planning, (quality management system planning), responsibility, authority and communication, management review, 6. Resource management – provision of resources, human resources, infrastructure, work environment, 7. Product realisation – planning for product realisation, customer related processes, design and development, purchasing, production and service provision, control of monitoring and measuring devices, 8. Measurement, analysis and improvement.

I SOLVED PROBLEMS

1. *Last weeks visual inspection carried out to find defectives in a manufactured item revealed the following data for a sample size of 30 numbers:*

This week, 30 pieces were again inspected on each of the two occasions and 6 pieces and 9 piece were found to be defective in each case respectively. Determine whether the process is under statistical control or not, this week.

Solution :

Since sample sign (n) in constant for all the 20 subgroups, we have to construct the np chart (*i.e.*, Number of defectives chart) and establish the central line, upper control limit and lower control limit values for the number of defectives (c) per subgroup.

Subgroup number	Number of defectives	Sub group number	Number of defectives(c)
1	5	11	5
2	4	12	7
3	4	13	4
4	4	14	5
5	7	15	4
6	4	16	5
7	5	17	5
8	6	18	7
9	4	19	6
10	5	20	5
			$\Sigma c = 101$

Central line = $n\bar{p}$

where $\bar{p}$ is the average fraction defective

$$\bar{p} = \frac{\text{Sum of all the defectives}}{\text{Number of sub - groups} \times \text{sample size (n)}} = \frac{\sum np}{K \times n}$$

where K = number of sub-groups ; n = Sample size

In this problem, K = 20, n = 30

Fraction defective $p = \frac{c}{n}$ where 'c' is the number of defectives

$$c = np \qquad \therefore \quad \bar{p} = \frac{\sum np}{K \times n} = \frac{\sum c}{K \times n}$$

$$\Sigma c = [5 + 4 + 4 + 5 + 7 + 4 + 5 + 6 + 4 + 5 + 5 + 7 + 4 + 5 + 4 + 5 + 7 + 6 + 5]$$

$$= 101$$

$$\bar{p} = \frac{101}{20 \times 30} = \frac{101}{600} = 0.168$$

$$\textbf{central line} = n\bar{p} = \frac{101}{600} \times 30 = \frac{101}{20} = \mathbf{5.05}$$

$$\textbf{upper control limit UCL} = n\bar{p} + 3\sqrt{n\bar{p}\left(1 - \bar{p}\right)}$$

$$= 5.05 + 3\sqrt{5.05\,(1 - 0.168)}$$

$$= 5.05 + 3\sqrt{5.05 \times 0.832} = 5.05 + 3.\sqrt{4.20}$$

$$= 5.05 + (3 \times 2.05)$$

$$= 5.05 + 6.15 = \mathbf{11.20}$$

$$\textbf{Lower control limit} = n\bar{p} - 3\sqrt{n\bar{p}\left(1 - \bar{p}\right)}$$

$$= 5.05 - 6.15 = \mathbf{-1.10 = 0 \text{ (if negative)}}$$

For 2 subgroups from which sample are inspected this week, the defectives found were 6 nos. and 9 nos. Since these values of defectives are less than the upper central limit (*i.e.*, 11.20) and more than lower control limit (*i.e.*, zero) the process is under statistical control.

2. *Construct both $\bar{X}$ and R chart from the following data.*

Sub-group number	$\bar{X}$	R	Sub-group number	$\bar{X}$	R
1	6.36	0.10	11	6.32	0.18
2	6.38	0.18	12	6.30	0.10
3	6.35	0.17	13	6.34	0.11
4	6.39	0.20	14	6.39	0.14
5	6.32	0.15	15	6.37	0.17
6	6.34	0.16	16	6.36	0.15
7	6.40	0.13	17	6.35	0.18
8	6.33	0.18	18	6.35	0.13
9	6.37	0.16	19	6.34	0.18
10	6.33	0.13	20	6.34	0.16

Assume constant values $A_2 = 0.73$, $D_3 = 0$, $D_4 = 2.28$.

(VTU - MBA, June/July 2003, New Scheme)

Solution :

For the construction of $\bar{X}$ – R chart.

The following formulae are used.

(a) For mean chart ($\bar{X}$ Chart) :

$$\textbf{Central line, } \bar{\bar{X}} = \frac{\sum \bar{X}}{K}$$

Where K = number of sub-groups = 20

$$\bar{\bar{X}} = \frac{127.03}{20} = \mathbf{6.351} \qquad \bar{R} = \frac{\sum R}{K} = \frac{3.06}{20} = \mathbf{0.153}$$

$$\textbf{Upper control limit } UCL_{\bar{X}} = \bar{\bar{X}} + A_2\bar{R}$$
$$= 6.351 + 0.73 \times 0.153$$
$$= 6.351 + 0.112 = \mathbf{6.463}$$

$$\textbf{Lower control limit } LCL_{\bar{X}} = \bar{\bar{X}} - A_2\bar{R}$$
$$= 6.351 - 0.112 = \mathbf{6.239}$$

(b) For range chart (R chart):

$$\textbf{Central line} = \bar{R} = \mathbf{0.153}$$

$$\textbf{Upper control limit } (UCL_R) = D_4\bar{R}$$
$$= 2.28 \times 0.153 = 0.349$$

$$\textbf{Lower control limit } (LCL_R) = D_3\bar{R} = \textbf{Nil}$$

3. *For the following data, construct a fraction defective chart.*

Group number	Sample Size	No. of defectives
1	32	2
2	32	3
3	50	3
4	50	2
5	32	1
6	80	4
7	50	2
8	50	0
9	32	2
10	32	1

Solution :

Since the sample size is varying, we have to construct p-chart (fraction defective chart) for varying sample size. Since the sample size is varying the control chart has varying control limits.

$$\text{Control line CL} = \bar{p} = \frac{\sum p}{K} \qquad p = \frac{c}{n} = \frac{\text{Number of defectives}}{\text{Sample size}}$$

Group Number	Fraction defective (p)
1	2/32 = 0.0625
2	3/32 = 0.0940
3	3/50 = 0.0600
4	2/50 = 0.0400
5	1/32 = 0.0300
6	4/80 = 0.0500
7	2/50 = 0.0400
8	0/50 = 0.000
9	2/32 = 0.0625
10	1/32 = 0.0300
K = 10	Total (Σp) = 0.469

$$\bar{p} = \frac{\sum p}{K} = \frac{0.469}{10} = 0.0469 = \mathbf{0.047}$$

$$\textbf{Upper control limit (UCL)} = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{\text{Sample size } (n)}}$$

$$\textbf{Lower control limit (LCL)} = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{\text{Sample size } (n)}}$$

Since sample size (n) is varying, we have to calculate the UCL and LCL for all sample sizes of n = 32, n = 50 , n = 80.

For n = 32,

$$\textbf{UCL} = 0.047 + 3\sqrt{\frac{0.047\,(1-0.047)}{32}}$$

$$= 0.047 + 3\sqrt{\frac{0.047 \times 0.953}{32}}$$

$$= 0.047 + 3 \times 0.037 = 0.047 + 0.111 = \mathbf{0.158}$$

$$\textbf{LCL} = 0.047 - 0.111 = \mathbf{0 \text{ (if negative)}}$$

For n = 50

$$\textbf{UCL} = 0.047 + 3\sqrt{\frac{0.047 \times 0.953}{50}}$$

$$= 0.047 + 3 \times 0.0299 = 0.047 + 0.0897 = \mathbf{0.136}$$

$$\textbf{LCL} = 0.047 - 0.0897 = \mathbf{NIL \text{ (if negative)}}$$

For n = 80,

$$\textbf{UCL} = 0.047 + 3\sqrt{\frac{0.047 \times 0.953}{80}}$$

$$= 0.047 + 3 \times 0.0236 = 0.047 + 0.709 = \mathbf{0.117}$$

$$\textbf{LCL} = 0.047 - 0.0709 = \mathbf{Nil \text{ (if negative)}}$$

4. *Construct a 'c' chart or 'number of defects' chart for the following data.*

Sub group	Sample size (n)	No. of defects (e)
1	1	15
2	1	28
3	1	41
4	1	26
5	1	26
6	1	35
7	1	40
8	1	24
9	1	10
10	1	38

Solution :

For the 'c' chart or number of defects chart for constant sample size.

$$\textbf{Central line} = \bar{c} = \frac{\text{Total number of defects}}{\text{Total number of samples}}$$

$$= \frac{\sum c}{k} = \frac{283}{10} = \mathbf{28.3}$$

$$\textbf{Upper control limit (UCL)} = \bar{c} + 3\sqrt{\bar{c}}$$

$$= 28.3 + 3\sqrt{28.3} = \mathbf{44.26}$$

$$\textbf{Lower control limit (LCL)} = \bar{c} - 3\sqrt{\bar{c}}$$

$$= 28.3 - 3\sqrt{28.3}$$

$$= 28.30 - 15.96 = \mathbf{12.34}$$

Testing for homogeneity : Comparing all the values of 'c' with the values of UCL and LCL, it may be noted that sub-group number 9 has 'c' values less than LCL. Hence deleting the sample values for sub-group no. 9.

$$\text{Modified central line } \bar{c} = \frac{\sum c}{\sum n} \quad \text{where } n = 9$$

$$\bar{c} = \frac{273}{9} = \mathbf{30.33}$$

$$\text{Modified UCL} = \bar{c} + 3\sqrt{30.33}$$

$$= 30.33 + 16.52 = \mathbf{46.85}$$

$$\textbf{Modified LCL} = \bar{c} - 3\sqrt{\bar{c}}$$

$$= 30.33 - 3\sqrt{30.33}$$

$$= 30.33 - 16.52 = \mathbf{13.81}$$

Now by comparing all individual values of 'c' for the 9 sub-groups, we can see that all values of c for 9 sub-groups fall between UCL an LCL and the test for homogeneity is satisfied.

Group Number	Fraction defective (p)
1	2/32 = 0.0625
2	3/32 = 0.0940
3	3/50 = 0.0600
4	2/50 = 0.0400
5	1/32 = 0.0300
6	4/80 = 0.0500
7	2/50 = 0.0400
8	0/50 = 0.000
9	2/32 = 0.0625
10	1/32 = 0.0300
K = 10	Total (Σp) = 0.469

$$\bar{p} = \frac{\sum p}{K} = \frac{0.469}{10} = 0.0469 = \mathbf{0.047}$$

$$\textbf{Upper control limit (UCL)} = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{\text{Sample size } (n)}}$$

$$\textbf{Lower control limit (LCL)} = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{\text{Sample size } (n)}}$$

Since sample size (n) is varying, we have to calculate the UCL and LCL for all sample sizes of n = 32, n = 50 , n = 80.

For n = 32,

$$\textbf{UCL} = 0.047 + 3\sqrt{\frac{0.047\,(1-0.047)}{32}}$$

$$= 0.047 + 3\sqrt{\frac{0.047 \times 0.953}{32}}$$

$$= 0.047 + 3 \times 0.037 = 0.047 + 0.111 = \mathbf{0.158}$$

$$\textbf{LCL} = 0.047 - 0.111 = \mathbf{0 \text{ (if negative)}}$$

For n = 50

$$\textbf{UCL} = 0.047 + 3\sqrt{\frac{0.047 \times 0.953}{50}}$$

$$= 0.047 + 3 \times 0.0299 = 0.047 + 0.0897 = \mathbf{0.136}$$

$$\textbf{LCL} = 0.047 - 0.0897 = \mathbf{NIL \text{ (if negative)}}$$

For n = 80,

$$\textbf{UCL} = 0.047 + 3\sqrt{\frac{0.047 \times 0.953}{80}}$$

$$= 0.047 + 3 \times 0.0236 = 0.047 + 0.709 = \mathbf{0.117}$$

$$\textbf{LCL} = 0.047 - 0.0709 = \mathbf{Nil \text{ (if negative)}}$$

6. *Draw a $\bar{X} - \bar{R}$ chart for the following:*

Sum of mean of all sample $\sum \bar{X} = 585$.

Sum of the ranges of all samples $\sum \bar{R} = 410$

Number of samples = 20

Sample size = 5 each

$A_2 = 0.58,\ D_4 = 2.28,\ D_3 = 0$

Solution :

For $\bar{X}$ chart (mean chart)

$$\textbf{Central line CL} = \bar{\bar{X}} = \frac{\sum \bar{X}}{k}$$

where k = number of samples = 20

$$\bar{\bar{X}} = \frac{585}{20} = \mathbf{29.25}$$

For range chart or R chart,

$$\textbf{Central line} = \bar{R} = \frac{\sum R}{k} = \frac{410}{20} = \mathbf{20.5}$$

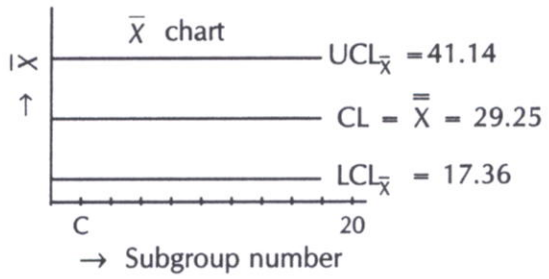
For $\bar{X}$ *chart,*

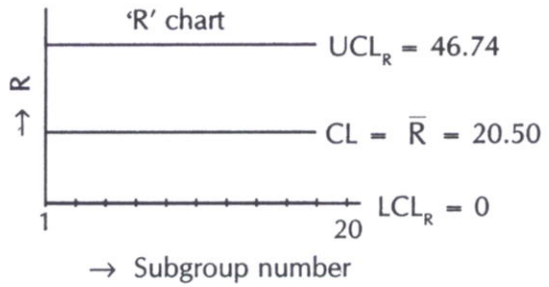
Upper control limit $(UCL_{\bar{X}}) = \bar{\bar{X}} + A_2\bar{R}$

$= 29.25 + 0.58 \times 20.5$

$= 29.25 + 11.89 = \mathbf{41.14}$

Lower control limit $(LCL_{\bar{X}}) = \bar{\bar{X}} + A_2\bar{R} = 29.25 - 11.89 = \mathbf{17.36}$





For R chart,

Upper control limit $(UCL_{\bar{R}}) = D_4\bar{R}$

$= 2.28 \times 20.5$

$= 46.74$

Lower control limit $(LCL_{\bar{R}}) = D_3\bar{R} =$ Nil.

6. *10 samples (each of size 100) of a component were inspected. The results of the inspection are given below:*

Sample no.	1	2	3	4	5	6	7	8	9	10
No. of defectives	2	0	4	3	1	2	3	1	1	2

Draw the relevant control chart taking 3 sigma limits.

Solution :

Since the sample size is constant, we have to draw 'np' chart (fraction defectives chart for constant sample size).

Sample size n = 100

No. of samples (sub-groups) k = 10

No. of defectives per sub-group = c

$$\textbf{fraction defective } p = \frac{c}{n}$$

$$\textbf{Central line} = n\bar{p} = n \times \frac{\sum p}{n} = \frac{n \times \sum c/n}{k} = \frac{\sum c}{k} = \frac{19}{10} = \mathbf{1.9}$$

$$\textbf{Upper control limit} = n\bar{p} + 3\sqrt{n\bar{p}\left(1-\bar{p}\right)}$$

$$= 1.9 + 3\sqrt{1.9\,(1 - 1.9/100)}$$

$$= 1.9 + 3\sqrt{1.9 \times 0.981}$$

$$= 1.9 + 3\sqrt{1.864}$$

$$= 1.9 + 3 \times 1.365$$

$$= 1.9 + 4.095 = 6.0$$

$$\textbf{Lower control limit} = n\bar{p} - 3\sqrt{n\bar{p}\left(1-\bar{p}\right)}$$

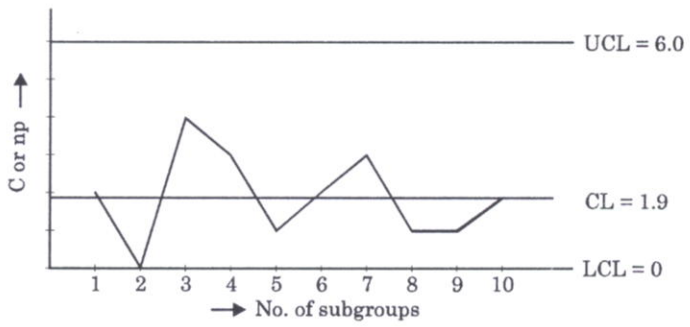
$$= 1.9 - 3 \times 1.365$$

$$= 1.9 - 4.095$$

$$= -2.2$$

= Nil (if negative)

Construction of 'np' chart



7. *Calculate the process capability from the given data. 20 samples of 5 each were measured and the readings are* $\sum \bar{X} = 585$. $\sum R = 410$, $d_2 = 2.33$.

Solution :

Sample size (n) = 5

No. of samples (sub-groups) (k) = 20

$\sum \bar{X} = 585$; $\sum R = 10$; $d_2 = 2.33$.

Central line for $\bar{x}$ chart (mean chart) $= \bar{\bar{X}} = \dfrac{\sum \bar{X}}{k} = \dfrac{585}{20} = 29.25$

Central line for Range chart (chart) $= \bar{R} = \dfrac{\sum R}{k} = \dfrac{410}{20} = 20.50$

Upper control limit for $\bar{X}$ chart $(UCL_{\bar{x}})$ $= \bar{\bar{X}} + A_2\bar{R}$

Constant $A_2 = \dfrac{3}{\sqrt{n} \times d_2} = \dfrac{3}{\sqrt{5} \times 2.33}$

$= \dfrac{3}{2.23 \times 2.33} = \dfrac{3}{5.20} = 0.576 = \mathbf{0.58}$

Upper control limit $(UCL_{\bar{x}})$ $= 29.25 + 0.58 \times 20.50$

$= 29.25 + 11.89 = \mathbf{41.14}$

Lower control limit $(LCL_{\bar{x}})$ $= \bar{\bar{X}} + A_2\bar{R} = 29.25 - 11.89 = \mathbf{17.36}$

8. *Samples of 4 each were taken for study, the measurement of which were noted as follows:*

Sample No.	Measurements in mm			
1	20	22	25	24
2	18	23	20	26
3	24	25	22	20
4	23	21	26	24
5	24	25	24	21

Draw a control chart for mean ($A_2 = 0.73$ for sample size 4).

Solution :

To construct $\bar{X} - R$ *chart, first calculate the mean (i.e.,* $\bar{X}$*) for each sample number as below:*

Sample No.	$\bar{X}$ (mean value of measurement $= \sum x/n$ where n = sample size = 4)
1	$\frac{20 + 22 + 25 + 24}{4} = 22.75$
2	21.75
3	22.75
4	23.50
5	23.50

Central line for $\bar{X}$ *(man) chart* $= \bar{\bar{X}} = \frac{\sum \bar{X}}{k}$

Where k = number of sub-groups = 5.

$$\therefore \bar{\bar{X}} = \frac{22.75 + 21.75 + 22.75 + 23.75 + 23.5}{5} = \mathbf{22.85}$$

Calculation of range :

$\therefore$ Range $= (X_{max.} - X_{min.})$ for each sample number

Sample No.	Measurements in mm
1	25 – 20 = 5
2	26 – 18 = 8
3	25 – 20 = 5
4	26 – 21 = 5
5	25 – 21 = 4

Average of range $= \bar{R} = \frac{\sum R}{k} = \frac{5+8+5+5+4}{5} = \frac{27}{5} = \mathbf{5.40}$

Upper control limit for $\bar{X}$ chart ($UCL_{\bar{X}}$) $= \bar{\bar{X}} + A_2\bar{R}$

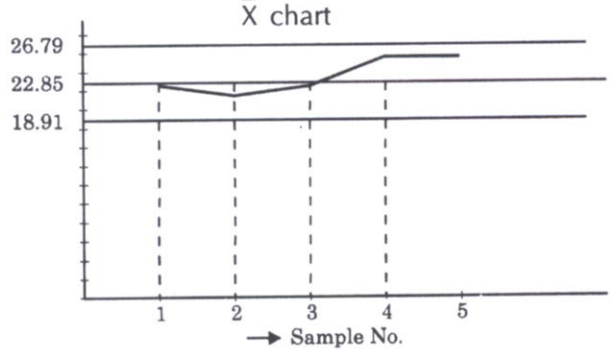
$= 22.85 + 0.73 \times 5.4$

$= 22.85 + 3.94 = \mathbf{26.79}$

Lower control limit for $\bar{X}$ chart ($LCL_{\bar{X}}$) $= \bar{\bar{X}} - A_2\bar{R} = 22.85 - 3.94 = \mathbf{18.91}$

Since all $\bar{X}$ values for 5 groups fall between the values of $UCL_{\bar{X}}$ and $LCL_{\bar{X}}$, all values of $\bar{X}$ are homogeneous.

Construction of mean or $\bar{X}$ chart.



9. *Construct a 'u' chart or "number of defects per unit" chart for the following data.*

Sub group	Sample size	No. of defects
1	1	15
2	1	28
3	1	41
4	1	26
5	1	26
6	1	35
7	1	40
8	1	24
9	1	10
10	1	38

Solution :

Calculate the number of defects per unit (u) for each sub group i.e., $u = \frac{c}{n}$.

Then central line $= \bar{u} = \frac{\Sigma u}{K}$, where $K = 10$, $\Sigma u = 170.5$, $\bar{u} = \frac{170.5}{10} = 17.05$

Upper control lime for $n_1 = 1$, $UCL = \bar{u} + \sqrt{\frac{\bar{u}}{n_1}} = 29.43$

$LCL = \bar{u} - \sqrt{\frac{\bar{u}}{n_1}} = 4.6$

Similarly, for $n_2 = 2$, $UCL = 25.81$; $LCL = 8.29$

for $n_3 = 3$, $UCL = 24.20$; $LCL = 9.89$

QUESTIONS

1. Distinguish between inspection and quality control.
2. State the objectives of inspection.
3. What is quality assurance?
4. What is "Quality at the source"?
5. What is "inspection"? Discuss the nature of inspection.
6. What is quality? Mention the various dimensions of product quality.
7. Discuss the scope of inspection.
8. How do you address the following questions regarding inspection activities? Explain your answer.
   (a) How much to inspect and how often?
   (b) Where to inspect in a process?
9. What is quality control? What are its objectives and benefits?
10. What is statistical quality control? What are its advantages?