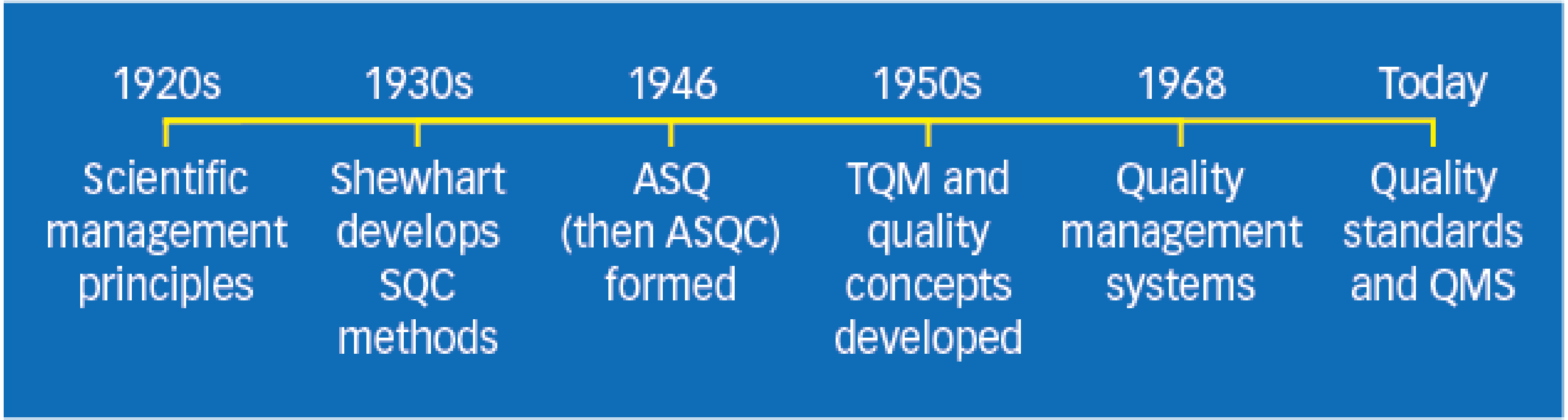
HISTORY OF TOTAL QUALITY MANAGEMENT

The history of quality methodology began initially as a term coined by the Naval Air Systems Command to describe its Japanese-style management approach to quality improvement. An umbrella methodology for continually improving the quality of all processes, it draws on a knowledge of the principles and practices of:

- The behavioral sciences
- The analysis of quantitative and nonquantitative data
- Economics theories
- Process analysis



1920s	• Some of the first seeds of quality management were planted as the principles of scientific management swept through U.S. industry. • Businesses clearly separated the processes of planning and carrying out the plan, and union opposition arose as workers were deprived of a voice in the conditions and functions of their work. • The Hawthorne experiments in the late 1920s showed how worker productivity could be impacted by participation.

1930s	•Walter Shewhart developed the methods for statistical analysis and control of quality.
1950s	•W. Edwards Deming taught methods for statistical analysis and control of quality to Japanese engineers and executives. This can be considered the origin of TQM. •Joseph M. Juran taught the concepts of controlling quality and managerial breakthrough. •Armand V. Feigenbaum's book *Total Quality Control,* a forerunner for the present understanding of TQM, was published. •Philip B. Crosby's promotion of zero defects paved the way for quality improvement in many companies.
1968	•The Japanese named their approach to total quality "companywide quality control." It is around this time that the term quality management systems arises. •Kaoru Ishikawa's synthesis of the philosophy contributed to Japan's ascendancy as a quality leader.
Today	•TQM is the name for the philosophy of a broad and systemic approach to managing organizational quality. •Quality standards such as the ISO 9000 series and quality award programs such as the Deming Prize and the Malcolm Baldrige National Quality Award specify principles and processes that comprise TQM. •TQM as a term to describe an organization's quality policy and procedure has fallen out of favor as international standards for quality management have been developed. Please see our series of pages on quality management systems for more information.

History of Quality Methodology

- Science of modern quality methodology started by R. A. Fisher perfected scientific shortcuts for shifting through mountains of data to spot key cause-effect relationships to speed up development of crop growing methods

- Statistical methods at Bell Laboratories: W. A. Shewhart transformed Fisher's methods into quality control discipline for factories (inspired W.E. Deming and J. M. Juran); Control Charts developed by W. A. Shewhart; Acceptance sampling methodology developed by H. F. Dodge and H. G. Romig

- World War II: Acceptance of statistical quality control concepts in manufacturing industries (more sophisticated weapons demanded more careful production and reliability); The American Society for Quality Control formed (1946).

- Quality in Japan: W.E. Deming invited to Japan to give lectures; G. Taguchi developed "Taguchi method" for scientific design of experiments; The Japanese Union of Scientists and Engineers (JUSE) established "Deming Price" (1951); The Quality Control Circle concept is introduced by K. Ishikawa (1960).

Statistical methods for quality improvement

Statistical methods in **quality improvement** are defined as the use of collected data and quality standards to find new ways to improve products and services. They are a formalized body of techniques characteristically involving attempts to infer the properties of a large collection of data.

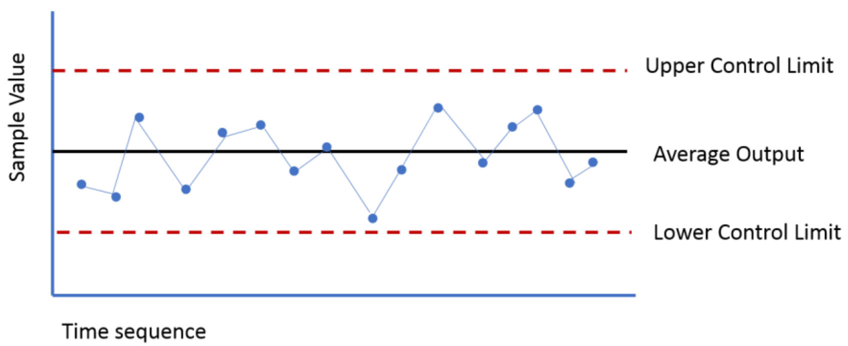
Many tools for quality control and improvement are management-related, not statistical.
Eg. quality circles, 14-point plans, and so on. These are outside the scope of this course.

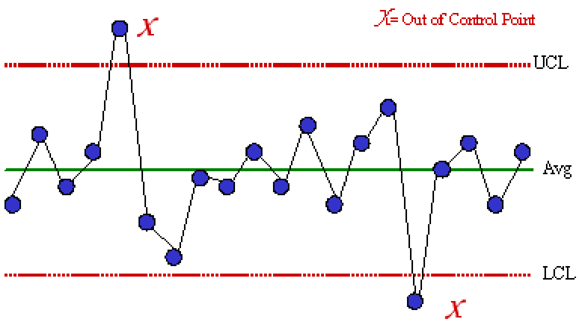
Major statistical areas
- Statistical process control
- Design of experiments
- Acceptance sampling

Statistical process control

Example: the control chart:

- Measure a quality characteristic in a sample from the process;
- Examples:
  - -Diameters of engine shafts sampled from the production line;
  - - Refund times for one day;
- Plot against time to look for changes.





In control:

Change in level:

Design of experiments (DoE)

Designed experiments are used to find the key factors that influence a quality characteristic, and to characterize their effects.

DoE is often used off-line; that is, not as part of the routine operation of the process.

Factorial designs use all combinations of chosen levels of the factors of interest.

At an early stage, many factors may be screened for effects, and a fractional factorial design may be used.

Acceptance sampling:

A tool used in managing product quality.

Example A manufacturer ships 45oz boxes of detergent to a retailer. The contract specifies that no more than 2% of boxes should have contents outside the specification limits.
The retailer inspects a sample of boxes from a shipment on arrival, and if too many are nonconformant, the whole shipment is returned to the manufacturer.

- How many boxes should be sampled?
- How many nonconformant boxes should be allowed?

Note:
The manufacturer has an incentive to improve quality by reducing variability, to reduce the cost of returned shipments.

Quality management Philosophy

- Dr. w. Edwards Deming:(1900-1993) is considered to be the father of modern quality

- Dr. Deming preached that to achieve the highest level of performance requires more than a good philosophy the organization must change its behavior and adopt new ways of doing business.

- Deming approach were amply summed up in his famous 14 points.

Deming’s 14 Principles.

1.“Create Constancy of Purpose”

- Define the problems of today and the future ¾Allocate resources for long-term planning
- Allocate resources for research and education
- Constantly improve design of product and service

2.“Adopt A New Philosophy”

- Quality costs less not more
- Superstitious learning
- The call for major change
- Stop looking at your competition and look at your customer instead

3.“Cease Dependence On Inspection For Quality”

- Quality does not come from inspection
- Mass inspection is unreliable, costly, and ineffective
- Inspectors fail to agree with each other
- Inspection should be used to collect data for process control

7. "Adopt And Institute Leadership"

- Remove barriers to pride of workmanship
- Know the work they supervise
- Know the difference between special and common cause of variation

8. "Drive Out Fear"

- The common denominator of fear:
- Fear of knowledge
- Performance appraisals
- Management by fear or numbers

9. "Break Barriers Between Staff Areas"

- Know your internal suppliers and customers
- Promote team work

10. "Eliminate Slogans, Exhortations And Targets"

- They generate frustration and resentment
- Use posters that explain what management is doing to improve the work environment

11.“Eliminate Numerical Quotas”

- They impede quality ¾They reduce production
- The person’s job becomes meeting a quota

12.“Remove Barriers That Rob Pride Of Workmanship”

- Performance appraisal systems ¾Production rates
- Financial management systems
- Allow people to take pride in their workmanship

13.“Institute Programs For Education And Self Improvement”

- Commitment to lifelong employment
- Work with higher education needs
- Develop team building skills

14.“Put Everybody In The Company To Work For This Transformation”

- Struggle over the 14 points
- Take pride in new philosophy
- Include the critical mass of people in the change

Quality and productivity

Quality can be defined as conformity to requirements. In other words, quality is the sum of features and characteristics of a product or service that bear on its ability to satisfy a given need. This includes economic need as well as availability, easy maintenance, reliability, design and all the other characteristics of need

The basic elements of product quality are: performance, features, reliability, conformity, durability, serviceability, aesthetics and perceived quality.

Each is self-contained and distinct, for a product can be ranked high in one dimension and low in another.

The characteristics of Japanese quality control are described as follows

In a production process there are eight possible relationships between change in quality and change in quantity. They are:

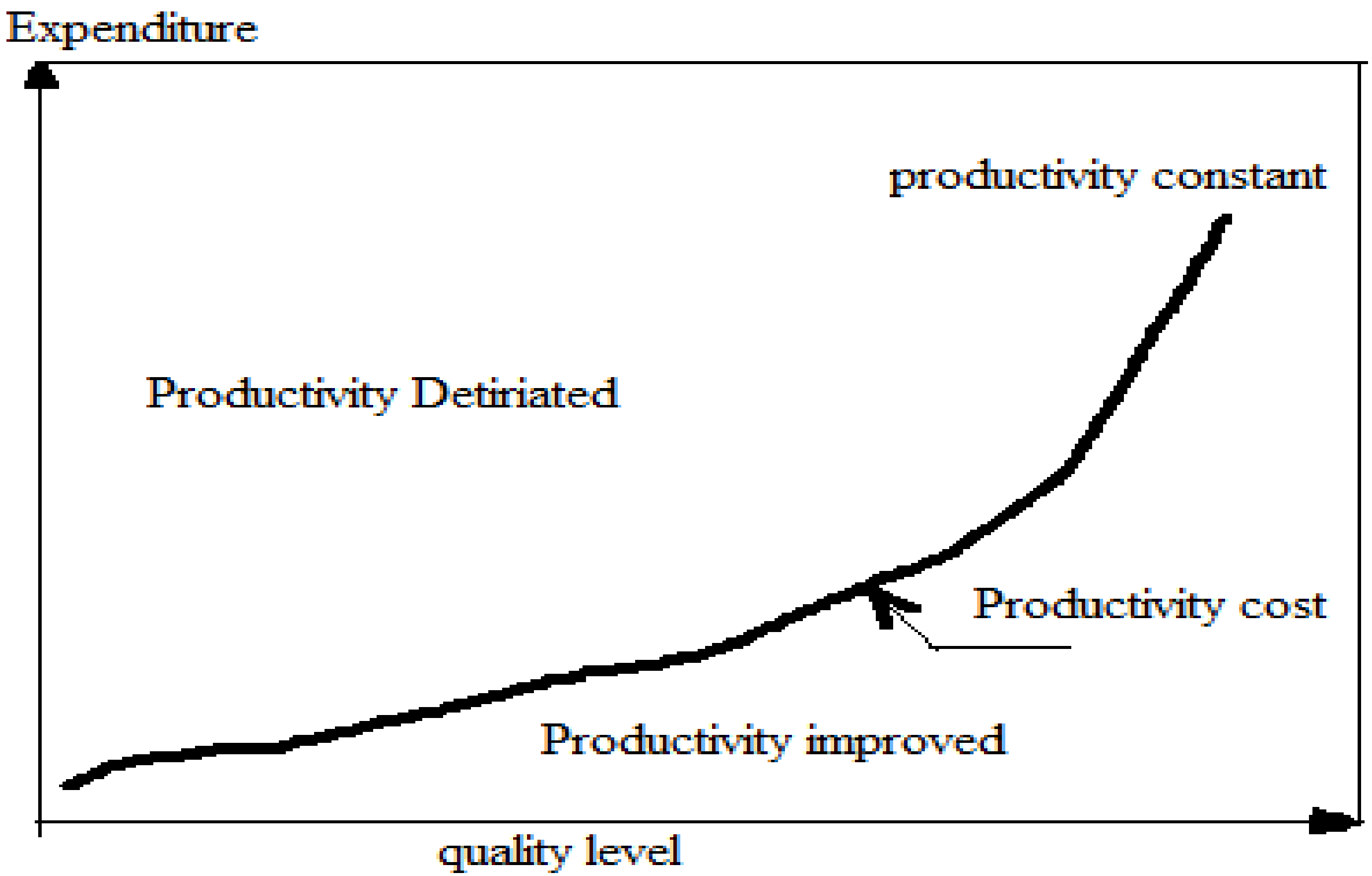
1. Quantity increases and quality improves.
2. Quantity increases but quality is the same.
3. Quantity is the same, but quality improves.
4. Quantity increases but quality deteriorates.
5. Quantity decreases but quality improves.
6. Quantity is the same but quality deteriorates.
7. Quantity decreases but quality is the same.
8. Quantity decreases and quality deteriorates.

It is evident that in cases 1, 2 and 3 productivity goes up, and in cases 6, 7 and 8 it goes down. But, in cases 4 and 5 it is not evident whether productivity goes up or not.

The relationships between productivity and quality are shown in the following formula:

$$\text{Production Cost} = \frac{\text{Total amount of effective input}}{\text{Total quantity of Products satisfy in quality level}}$$

The total amount of effective input equals the total amount of input minus the value of excessively rapid depreciation, which is not acceptable to the customer.

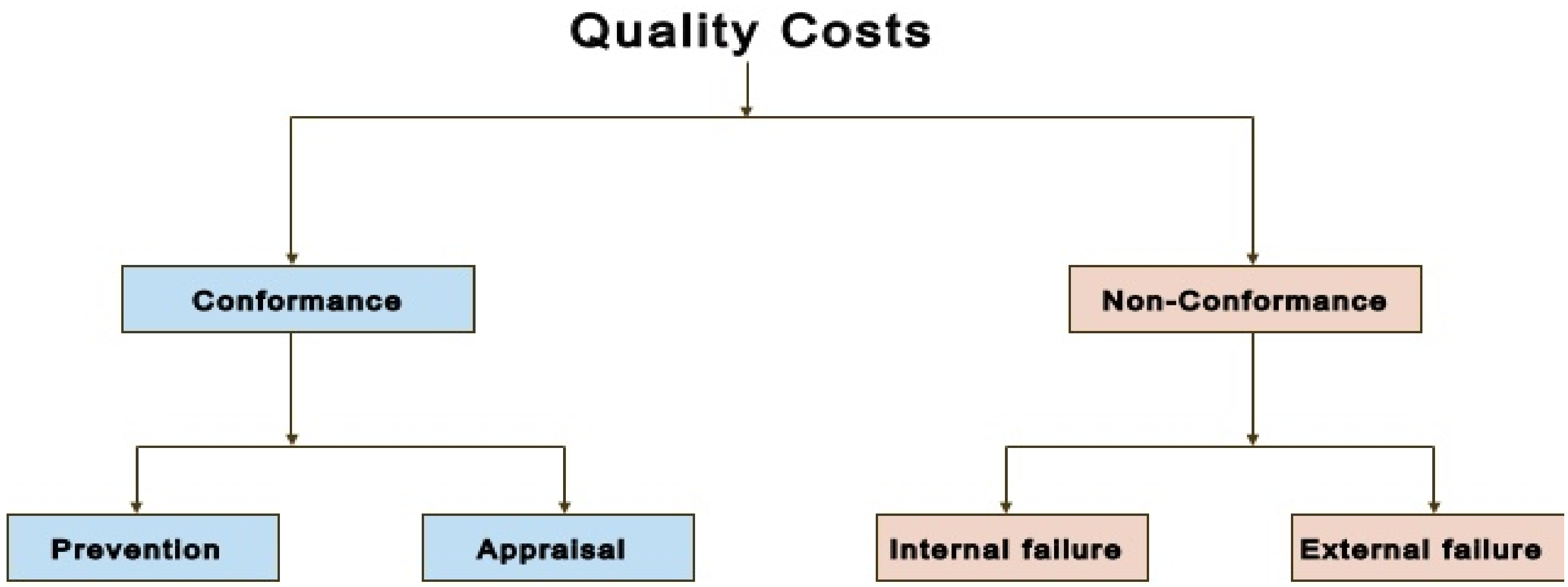


Relationships between quality and productivity

Quality Cost

1. Preventive cost
2. Appraisal cost
3. Internal failure cost
4. External failure cost

Categories of Quality Costs



Cost of quality

Cost of quality = Cost of conformance + Cost of non-conformance

- Cost of conformance is the cost of providing products or services as per the required standards. This can be termed as good amount spent. (Prevention & Appraisal costs)

- Cost of non-conformance is the failure cost associated with a process not being operated to the requirements. This can be termed as unnecessary amount spent.(Internal & External failure costs)

Preventive Cost: Any Efforts to Help People "Do it right the first time and all the time."

- Marketing, customer/user interaction
- Product/service/design development
- Purchasing and vendor partnership
- Operations (manufacturing/services)
- Quality engineering
- Quality administration
- Other prevention costs

Appraisal Cost: Testing, inspection and related equipment/supplies

- Purchasing appraisal cost: incoming goods or products
- Appraisal operations: testing and inspection
- External appraisal: field test outside company
- Data review
- Cost supporting appraisal efforts.

Preventive cost:
Do it right the first time

- Quality administration
- Quality engineering
- Management system certification

Internal Failure Cost: Defects/problems prior to shipping

- Product design failure
- Service failure
- Purchasing failure: incoming part failure
- Defectives/rejects/scraps/downgrading
- Repair or rework
- Materials review
- Corrective actions

External Failure Cost: Problems after Shipping

- Complaint investigations
- Problem solving
- Failure analysis
- Returned goods
- Retrofit and recall
- Warranty claims
- Liability costs
- Penalties
- Others

Mean or Sample Mean

Mean of a sample/Sample mean usually denoted by x, is the average and is computed as sum of all the observed outcomes from the sample divided by the total number of events.

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x$$

Where n is the sample size and the x correspond to the observed value.

<u>Example</u>-> Let there be the following numbers:

23, 29,20,32,23,21,33,25

$$\text{mean} = \frac{23+29+20+32+23+21+33+25}{8} = 25.75$$

MEDIAN

- The *median* is the middle score.
- If we have an even number of events we take the average of the two middles.
- The median is better for describing the typical value.
- It is often used for income and home prices.

<u>Example</u>: In previous example first we will write the numbers in order:

20,21,23,23,25,29,32,33

Median= $\frac{23+25}{2} = 24$

MODE

- The *mode* of a set of data is the number with the highest frequency.
- In previous example 23 occurs two times and every other number occur only once. Hence 23 is the mode.

VARIANCE AND STANDARD DEVIATION

- Calculate the mean, x.
- Write a table that subtracts the mean from each observed value.
- Square each of the differences.
- Add this column.
- Divide by n -1 where n is the number of items in the sample This is the *variance*.

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x-\bar{x})^2$$

- To get the *standard deviation* we take the square root of the variance.

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x-\bar{x})^2}$$

VARIANCE AND STANDARD DEVIATION

- Example:

x	X-25.75	$(X-25.75)^2$
23	-2.75	7.56
29	3.25	10.56
20	-5.75	33.06
32	6.25	39.06
23	2.75	7.56
21	-4.75	22.56
33	7.25	52.56
25	-.75	0.56
TOTAL		173.48

VARIANCE(S^2):

$$\frac{173.48}{8-1} = 24.78 = 25$$

Standard Deviation:

Sq. rt. (25) = 5

What Is a Z-Score?

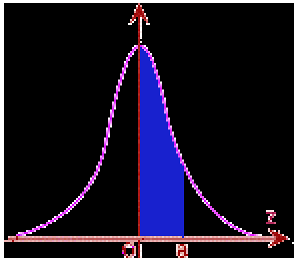
A Z-score is a numerical measurement that describes a value's relationship to the mean of a group of values. Z-score is measured in terms of standard deviations from the mean. If a Z-score is 0, it indicates that the data point's score is identical to the mean score. A Z-score of 1.0 would indicate a value that is one standard deviation from the mean. Z-scores may be positive or negative, with a positive value indicating the score is above the mean and a negative score indicating it is below the mean.

$$Z = \frac{raw\ score - mean}{standard\ deviation}$$

$$Z = \frac{X - \mu}{\sigma}$$

Where

X is the raw score
μ is the mean
σ is the standard deviation



Normal Distribution Table

a	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389

Chance & assignable causes of variation

Variation in quality of manufactured product in the respective process in industry is inherent & evitable. These variations are broadly classified as-
i) **Chance**/ Non assignable causes
ii) **Assignable** causes

i) **Chance Causes:**
In any manufacturing process, it is not possible to produce goods of exactly the same quality. Variation is inevitable. Certain small variation is natural to the process, being due to chance causes and cannot be prevented. This variation is therefore called *allowable*.

ii) **Assignable Causes:**
This type of variation attributed to any production process is due to non-random or so called assignable causes and is termed as *preventable variation*.
Assignable causes may creep in at any stage of the process, right from the arrival of the raw materials to the final delivery of goods.

Some of the important factors of assignable causes of variation **are-**

i) Substandard or defective raw materials
ii) New techniques or operation
iii) Negligence of the operators
iv) Wrong or improper handling of machines
v) Faulty equipment
vi) Unskilled or inexperienced technical staff and so on.

These causes can be identified and eliminated and are to discovered in a production process before the production becomes defective.

SQC is a productivity enhancing & regulating technique (**PERT**) with three factors-
i) Management
ii) Methods
iii) Mathematics

Here, control is two-fold- controlling the process (process control) & controlling the finished products (products control).

Central Limit Theorem

- Three principles
  - The mean of a sampling distribution is the same as the mean of the population
  - The standard deviation of the sampling distribution is the square root of the variance of sampling distribution $\sigma^2 = \sigma^2 / N$
  - The shape of a sampling distribution is approximately normal if either (a) N >= 30 or (b) the shape of the population distribution is normal

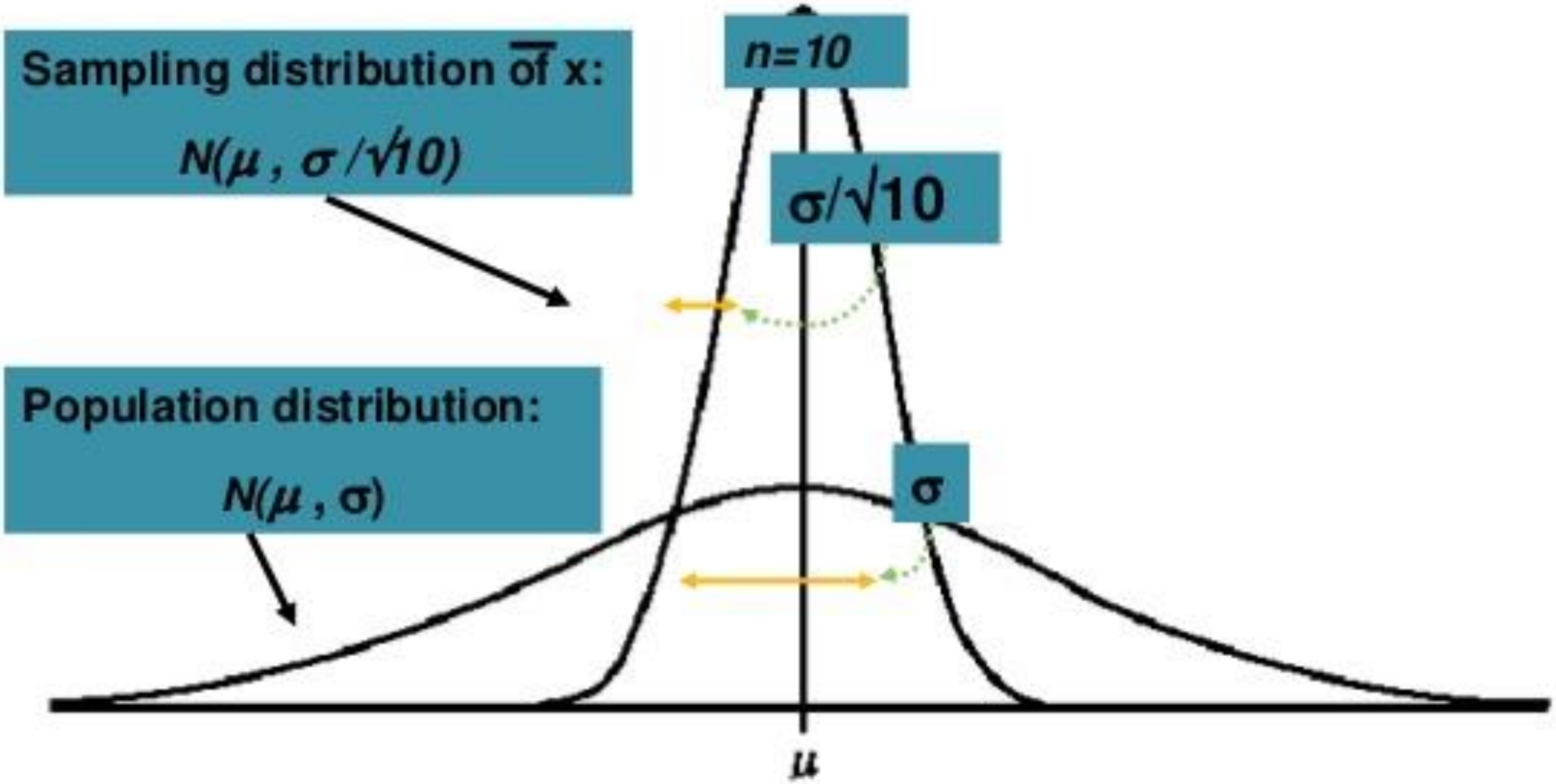
Introduction

- The Central Limit Theorem describes the relationship between the sampling distribution of sample means and the population that the samples are taken from.

Normal Populations

- **Important Fact:**
  - If the population is normally distributed, then the sampling distribution of x is normally distributed for any sample size n.

Sampling Distribution of x-normally distributed population



z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
–3.4	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0002
–3.3	.0005	.0005	.0005	.0004	.0004	.0004	.0004	.0004	.0004	.0003
–3.2	.0007	.0007	.0006	.0006	.0006	.0006	.0006	.0005	.0005	.0005
–3.1	.0010	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0007	.0007
–3.0	.0013	.0013	.0013	.0012	.0012	.0011	.0011	.0011	.0010	.0010
–2.9	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
–2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
–2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
–2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
–2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
–2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
–2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
–2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
–2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
–2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
–1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
–1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
–1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
–1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
–1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
–1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
–1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
–1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
–1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
–1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
–0.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
–0.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
–0.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
–0.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
–0.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
–0.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
–0.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
–0.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
–0.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
–0.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

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 can be used by a variety of industries and is considered one of the seven basic quality tools.

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

- Choose the appropriate control chart for your data.
- Determine the appropriate time period for collecting and plotting data.
- Collect data, construct your chart and analyze the data.
- 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.

BENEFITS OF USING CONTROL CHARTS

1. A control chart indicates when something may be wrong, so that corrective action can be taken.
2. The patterns of the plot on a control chart diagnosis possible cause and hence indicate possible remedial actions.
3. It can estimate the process capability of process.
4. It provides useful information regarding actions to take for quality improvement.

OBJECTIVES OF CONTROL CHARTS

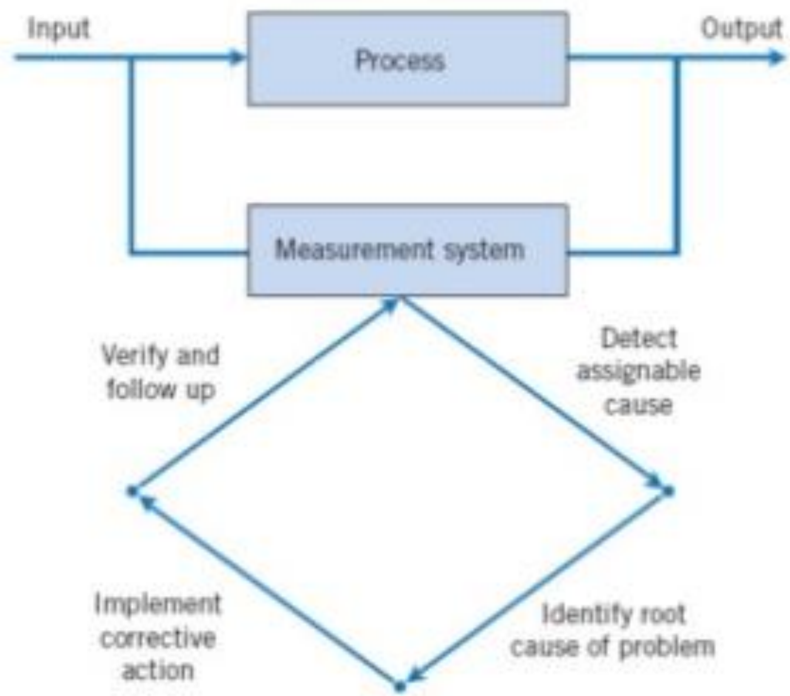
1. To secure information to be used in establishing or changing specifications or in determining whether the process can meet specifications or not.
2. To secure information to be used on establishing or changing production procedures.
3. To secure information to be used on establishing or changing inspection procedures or acceptance procedures or both.
4. To provide a basis for current decision during production.
5. To provide a basis for current decisions on acceptance for rejection of manufacturing or purchased product.
6. To familiarize personnel with the use of control chart.

Terms used in SQC Techniques Contd..

Type I error: - This is an error in sampling inspection. A sample from the output of a process may lead to the conclusion, that the process is out of control when, in fact it is operating as intended. Such an error is known as type I error.

Type II error: - This error occurs, when the process is not working as intended, but, sampling error causes one to infer that, the process is satisfactory.

Control Charts



Process improvement using the control chart.

Illustration 6.14: Control charts for $\overline{X}$ and R are to be established on a cert dimension of parts measured in mms. Data collected were of subgroup sizes (sam sizes) 6 and are given in Table 6.12 .

a. Compute the control limits or 3σ control limits or trial control limits both $\overline{X}$ and R

b. Draw the control chart

c. What conclusions can be drawn from the chart about the process.

Table 6.12

Given

Sub Group number	$\overline{X}$	R
1	20.35	0.34
2	20.40	0.36
3	20.36	0.32
4	20.65	0.36
5	20.20	0.36
6	20.40	0.35
7	20.43	0.31
8	20.37	0.34
9	20.48	0.30
10	20.42	0.37
11	20.39	0.29
12	20.38	0.30
13	20.40	0.33

Computed

Sub Group number	$\overline{X}$	R
14	20.41	0.36
15	20.45	0.34
16	20.34	0.36
17	20.36	0.37
18	20.42	0.73
19	20.50	0.38
20	20.31	0.35
21	20.39	0.38
22	20.39	0.33
23	20.40	0.32
24	20.41	0.34
25	20.40	0.30