• Dimension's of Quality :-

Quality can be described in several way's. Garvin provides an excellent discussion of eight component's / dimensⁿ of quality. They are as follows:-

1. Performance :- Customer's usually evaluates a product based on how it will perform certain specific functions and how well it performs.
2. Reliability :- (How often do a product fail?). Complex products require some repair in their service time/life. How often does it require a repair is the reliability of that product.
3. Durability :- (How long does it lasts?) The effective service life of a product. Constomers obviously wants their product to perform satisfactory over a long period of time.
4. Serviceability :- (How easy is it to repair?). In Many industries, Customers quality view is dependent on how quickly and economically a product's repair or maintanance is accomplised.
5. Aesthetics :- (What does product look like). It is the visual appeal of product. Some of the Aesthetic factor's are color, style, shape, packaging, etc.
6. Features :- Usually, costomer need's high quality product's that have added feature's - other than the basic one's. of the competitions.
7. Perceived Quality :- (What is reputatⁿ of Company/product) In many cases, customer's rely on past reputation of product/company. This reputatⁿ is influenced by failotures of product in past & how the customer's is treated when quality-related problems are reported. Perceived Quality, Customer loyalty, and repeated business are inter-connected
8. Conformance to Standards :- (Is product made exactly as designer intended?) We usually think highly-quality product as that exactly meet's the requirements Placed on it. An Automobile consist's of several thousand parts. If each one is ~~highly~~ slightly too-big/small, many components will not fit. & Vehicle may not perform as designer intended

In Service and Transcational business Organizatⁿ, we add the following:-

1. Responsiveness:- How long a service provider takes to reply to your request for service and how willing to helpful was he?
2. Professionalism:- The knowledge and skill of service provider the competency to provide the required services.
3. Attentivess:- How caring and personalized attension you get from service provider.

- Traditional Definition of Quality:- Based on the view-point that product and services must meet the requirements of those who use them. Quality means fitness for use.

There are two general aspect of fitness for use.

ⓐ Quality of Design:- All goods and services produced have various grades/level of quality. These variation are intentional and consequently appropriate technical term is quality of Design.

ⓑ Quality of Conformance:- How well product conforms to specificⁿ required by design. Influenced by factor's → Choice of manufac process; type of process control, tests etc.

- Modern Definition :- Quality is inversely proportional to Variability. This implies as the variability increases the Quality of Product Decreases. It result's to defining the quality Improvement.

- Quality Improvement :- It is the reduction of Variability of process and products.

ⓐ Reduction of waste:- particularly effective in Service Industries where there may not be as many thing's than can be directly measured. In service industry, by improving service process, the wasted effort & expense (for an error/mistake) can be avoided.

Non-Conforming :- those that fail to meet one or more of their specificatⁿ
non-Conformity :- Not necessarily unfit for use. Ex - A detergent with less conc (use more amt)

- Management Asspects of Quality Improvement ~~Assuarance~~ :-

① Quality Planning :- A strategic activity as vitial as Organization's long term business sucess plan, financial plan, marketing plan. Without this plan, enormous amount of time, money and effort will be wasted dealing with faulty design's, ~~mat~~ manufac. defects, etc. It involves identifying customers, both external & those operate internal to business. & indentifying their need's

② Quality Assuarance :- It is a set of activity that ensures quality levels of product and services are properly maintained & suppliers and customer's quality issues are properly resolved. Quality System documentation involves four components : ⓐ policy ⓑ procedure ⓒ Work instruction & ⓓ Sepecifications and ⓔ records.

ⓐ Policy → deal's with what to be done and why?

ⓑ Procedure → focus on methods & personnel that implement policy.

ⓒ Work instructⁿ & → are usually product, department, tool / machine-oriented specificatⁿ's.

ⓓ Records → way of documenting policies, procedures, & work ins. & spec. & also can used to track specific unit, so that to deterom. how it was produced

③ Quality Control and improvement :- involves set of activities used to ensure that products & services meet requirements and are improved on a continuous basis. Since Variability is major issue, Statistical technique, including SPC & design experiment are major tools ~~tools~~ of quality control and improvements.

- W. Edward's Demig's 14 points:-

He believed most of the opportunities for quality improvement require management action and very few opportunities lies at workforce or operator level. This philosphy is summarized in this 14 points:

1. Create a constancy of purpose focused on improvement of product's & services.

Management should constantly try to improve product design and performance. This must include investment in research, development & innovation, which have long-term payback to Organization

2. Adopt new philosophy that recognizes we are in differen economic era

Reject defective product's / bad service. It cost as much to produce defective units as it does to produce good ones (sometimes more). Cost to deal with scrap, rework created by defective is enormous drain of company resour

3. Do not rely on mass inspection to "control" quality.

Inspectⁿ just sorts out defectives, but does not saves cost to produce them. and Inspectⁿ itself is expensive & occur's too late in process & is inefficent

4. Do not award business to supplier's on the basis of price alone, but also consider quality.

Price is meaningful measure of supplier's product only if it is considered in relatⁿ with measure of quality. Preference should be given to suppliers who use modern method's of quality improv. in their business and demonstrate process control and capability. It is imp. to built effective, long term relatⁿ with supplier.

5. Focus on Continuous improvement.

Constantly try to improve the productⁿ and services using statistical method's and tool's.

6. Practice Modern training method's and invest it on the job training for all employees.
Everyone should be trained in the technical aspects of their jobs and in modern quality and productivity method as well as encourage

7. Improve leadership, and practice modern Supervision methods.
Supervisions should not be limited to only focus on survellience of worker's; but also to help the empolyee's improve the system in which they work. It should be to Improve work system & product.

8. Drive out fear:-
Management should eliminate the fear of worker's to ask question's, report problems or point condt" that barrier's to quality & effective prodct".

9. Break down the barrier's b/w functional area of business.
Teamwork among diff. organizat" units are essential for quality & productivity improvement to take place.

10. Eliminate target's, Slogan, and numerical goals for Workforce.
A target such as "zero defect" is useless without a plan for acheivement. Rather, work to improve the system and provide informat" on that.

11. Eliminate numerical quotas and work standard's.
These std's have historically been set without regard to quality. Work std are often symptoms of managent's inability to understand work process. and to provide an effective management system. focused on improving process.

12. Remove the barrier that discourage empolyee from doing their jobs.
Management's must often listen to employee's suggest", since he know's about job he's doing and may have valuable data. to make process work more efficient.

13. Institute an ongoing program of eductation for all employees.
Education is simple, powerful statistical ~~tegn~~ technique. should be mandatory for all employees. As employees understand SPC Problem solving tools and their uses, they will be more likely to look for ~~poor~~ cause of poor quality and to identify process improvement.

14. Create a structure in top management that will vigorously advocate the first 13 points.

- Juran Triology:-

The juran's quality mangement philosophy focuses on 3 Component's.
ⓐ Planning ⓑ Control ⓒ Improvement. These are known as Juran's Triology.

- Armand V. Feigenbaum's Total Quality ~~Control~~ Management (TQM):-

Inferences About Process Quality

Statistics and Sampling Distribution's :-

The objective of statistical inference is to draw conclusion or make decision about population based on a sample selected from population.

We define $x_1, x_2, ... x_n$ as a random sample of size n if it is ~~oft~~ selected so that $\{x_i\}$ are independent and identically distributed.

① The Sample Mean $= \frac{1}{n}\sum_{i=1}^{n} x_i = \bar{x}$

② Sample Variance $= \sum_{i=1}^{n} \frac{(x_i - \bar{x})}{n-1} = S^2$

③ Sample Std. Dev $= \sqrt{S^2} = S$

The probability Distribution of ~~Sample is~~ statistics/estimator is known as Sampling Distribution

① Sampling from Normal Distribution :-

if mean is μ and variance is σ^2 of normally distributed random variable x. If $x_1, x_2, x_3 ---- x_n$ is a random sample of size n. from this process, then. $\bar{x}$ be the sample mean, Now distribution of Sample mean $\bar{x}$ is. ~~$N(\bar{x},$~~ $N(\mu, \sigma^2/n)$

★Note :- From Central Limit theorem regardless, of distribution of population, the distribution of ~~random Variable~~ samples i.e Sampling distribution of Sample Mean is approximately $\bar{x} \sim N(\mu, \sigma^2/n)$

• Chi-Square Distribution :-

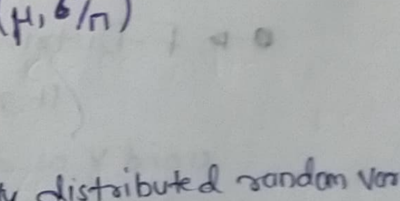
IF $x_1, x_2, x_3 --- x_n$ are normally and independtly distributed random variable with mean zero and Variance 1. then the random variable.

$$\chi_n^2 = x_1^2 + x_2^2 + x_3^2 + --- x_n^2$$

is distributed χ^2 (Chi-Square)

With. Degree of freedom n

$$f(\chi^2) = \frac{1}{2^{n/2}\,\Gamma(n/2)} (\chi^2)^{(n/2)-1} \cdot e^{-\chi^2/2}, \quad \chi^2 > 0$$



Here, $\mu = n$ and $\sigma^2 = 2n$. The distribution is skewed.

if $x_1, x_2, x_3 \cdots x_n$ is a random sample from an $N(\mu, \sigma^2)$. Then random variable

$$\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{\sigma^2} \sim \chi^2_{n-1} \quad \text{i.e} \quad \frac{(n-1)s^2}{\sigma^2} \sim \chi^2_{n-1} \qquad \chi_{n-1} = \frac{\sqrt{n-1}\,s}{\sigma}$$

The Sampling distribut^n of $(n-1)s^2/\sigma^2$ is χ^2_{n-1}, if populat^n is Normal distrib^n.

- **t-Distribution:-**

IF x and χ^2_k are independent (std. Normal and Chi-square, then

$$t_k = \frac{x}{\sqrt{\chi^2_k/k}} \quad \text{is distributed } t \text{ with } k \text{ degree of freedom.}$$

$$f(t) = \frac{\Gamma[(k+1)/2]}{\sqrt{k\pi}\,\Gamma(k/2)} \times \left(\frac{t^2}{k}+1\right)^{-(k+1)/2} \qquad -\infty < t < \infty$$

$\mu = 0;\ \sigma^2 = k/(k-2)$ for $k>2$

if $x_1, x_2 \cdots x_n$ is from $N(\mu, \sigma^2)$ distribut^n. $\bar{x}$ and s^2 are it's statisti

$$\frac{\bar{x}-\mu}{s/\sqrt{n}} = \frac{\bar{x}-\mu/\sigma/\sqrt{n}}{s/\sigma} = \frac{N(0,1)}{\sqrt{\chi^2_{n-1}/(n-1)}} \sim t_{n-1} \qquad \left[(n-1)s^2/\sigma^2 \sim \chi^2_{n-1}\right]$$

- **F-Distribut^n:-**

IF χ^2_u and χ^2_v are two independent chi-square distribut^n with u and v as d.o.f. then the ratio.

$$F_{u,v} = \frac{\chi^2_u/u}{\chi^2_v/v} \quad \text{is F-distributed.}$$

$$g(f) = \frac{\Gamma\left(\frac{u+v}{2}\right)(u/v)^{u/2}}{\Gamma(u/2)\,\Gamma(v/2)} \times \frac{f^{(u/2)-1}}{\left[(u/v)f+1\right]^{(u+v)/2}} \qquad 0 < f < \infty$$

For Our purpose:-

$$\frac{s_1^2/\sigma_1^2}{s_2^2/\sigma_2^2} \sim f_{n_1-1, n_2-1}$$

$$F_{1-\alpha/2, u, v} = \frac{1}{f_{\alpha/2, u, v}}$$

——— x ———

Note:- Imp:-

1. IF σ is known, the sample distribut^n follows $N(\bar{x}, \sigma/\sqrt{n})$ or Z test.
2. IF σ is Unknow, the sample distribut^n follows t_{n-1} $(\bar{x}, s)$

② Sampling from Bernoulli Distribution:-

$x_1, x_2, \dots x_n$ is taken from Bernoulli process. $\sim (P)$

$x = x_1 + \dots x_n \rightarrow$ has parameters n and P

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad = \{0, 1/n, 2/n, \dots 1\}$$

$$\therefore P\{\bar{x} \le a\} = P(x \le an) = \sum_{k=0}^{[an]} \binom{n}{k} p^k (1-p)^{n-k}$$

Here:- $\mu_{\bar{x}} = P$; $\sigma_{\bar{x}}^2 = \frac{p(1-p)}{n}$

③ Sampling from a poission Distribution:-

if $x_1 \dots x_n$ are taken from poission distribut" with parameter λ.

then, $x = x_1 + x_2 + \dots x_n$ is also poission with parameter $n\lambda$.

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \{0, 1/n, 2/n \dots\}$$

$$P(\bar{x} \le a) = P(x \le an) = \sum_{k=0}^{[an]} \frac{e^{-n\lambda}(n\lambda)^k}{k!}$$

Here:- $\bar{x} = \lambda$, $\sigma_{\bar{x}}^2 = \frac{\lambda}{n}$

• Estimation of Process Parameter:-

① Point Estimator:-

Two most important properties required for a good point estimator are:-

ⓐ Point estimtor should be unbiased. Expected value of point parameter. Should be parameter being estimated.

ⓑ Point estimator should have minimum Variance.

$\bar{x}$ and s^2 are unbiased estimators of population mean and variance.

but, s is not an unbiased estimator for populat" std. Dev.

Ex:-

Ⓐ Poission's Process:- $\mu = \lambda$ and $\sigma^2 = \lambda$

$$\hat{\lambda} = \frac{1}{n}\sum_{i=1}^{n} x_i = \bar{x} \rightarrow \text{point estimator of } \lambda.$$

Ⓑ Binomial Distribution:- $\mu = np$ and $\sigma^2 = np(1-p)$

$$\hat{P} = \frac{1}{n}\sum_{i=1}^{n} x_i = \bar{x} \rightarrow \text{point estimator of } P$$

(2) Interval Estimator:-

$$P(L \le \mu \le U) = \underbrace{(1-\alpha)}_{\text{confidence coefficient}}$$

The resulting interval $L \le \mu \le U$ is called $100(1-\alpha)\%$ confidence interval for unknown mean μ.

$$\underbrace{P(L \le \mu) = 1-\alpha}_{\text{one sided lower confi. Limit}} \quad \text{and} \quad \underbrace{P(U \ge \mu) = 1-\alpha}_{\text{one sided Upper Confidence Limit.}}$$

→ Confidence Intervals For Various Cases:-

$\frac{x - \mu}{\sigma/\sqrt{n}}$

(1) ON Mean for known Variance:- (Z-distribut^n)

(a) $\bar{x} - Z_{\alpha/2}\,\sigma/\sqrt{n} \le \mu \le \bar{x} + Z_{\alpha/2}\,\sigma/\sqrt{n}$ (For $100(1-\alpha)\%$ two-sided interval on μ)

(b) $\mu \le \bar{x} + \frac{Z_\alpha \sigma}{\sqrt{n}}$ → For upper confidence - One sided.

(c) $\mu \ge \bar{x} - \frac{Z_\alpha \sigma}{\sqrt{n}}$ → For Lower confidence - One sided.

(2) ON Mean of Normal Distb^n with Unknown Variance: (t-distribution)

(a) $\bar{x} - t_{\alpha/2, n-1}\frac{S}{\sqrt{n}} \le \mu \le \bar{x} + t_{\alpha/2, n-1}\frac{S}{\sqrt{n}}$ → Two sided test.

(b) $\mu \le \bar{x} + t_\alpha \frac{S}{\sqrt{n}}$ → upper confidence.

(c) $\mu \ge \bar{x} - t_{\alpha, n-1}\frac{S}{\sqrt{n}}$ → Lower Confidence

(3) ON Variance of Normal Distribution: (χ^2-distribution)

(a) $\frac{(n-1)S^2}{\chi^2_{\alpha/2, n-1}} \le \sigma^2 \le \frac{(n-1)S^2}{\chi^2_{1-\alpha/2, n-1}}$

(b) $\sigma^2 \le \frac{(n-1)S^2}{\chi^2_{1-\alpha, n-1}}$

(c) $\sigma^2 \ge \frac{(n-1)S^2}{\chi^2_{\alpha, n-1}}$

(4) ~~Co~~ ON Difference in Two Means with known Variance: (Z-distribut^n)

(a) $(\bar{x}_1 - \bar{x}_2) - Z_{\alpha/2}\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}} \le (\mu_1 - \mu_2) \le (\bar{x}_1 - \bar{x}_2) + Z_{\alpha/2}\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$

(b) $(\mu_1 - \mu_2) \le (\bar{x}_1 - \bar{x}_2) + Z_\alpha\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$

(c) $(\mu_1 - \mu_2) \ge (\bar{x}_1 - \bar{x}_2) - Z_\alpha\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$

5 ON Difference b/w means with Unknown Variance: (t-distⁿ)

Case I:- Assume $\sigma_1^2 = \sigma_2^2 = \sigma^2$

Combined estimate of common variance

(Pooled Estimate) $S_p^2 = \dfrac{(n_1-1)S_1^2 + (n_2-1)S_2^2}{n_1+n_2-2}$

(a) $(\bar{x}_1-\bar{x}_2) - t_{\alpha/2, n_1+n_2-2} \times S_p\sqrt{\frac{1}{n_1}+\frac{1}{n_2}} \le \mu_1-\mu_2 \le (\bar{x}_1-\bar{x}_2) + t_{\alpha/2, n_1+n_2-2} \times S_p\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}$

(b) $\mu_1-\mu_2 \le (\bar{x}_1-\bar{x}_2) + t_{\alpha, n_1+n_2-2}\, S_p\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}$

(c) $\mu_1-\mu_2 \ge (\bar{x}_1-\bar{x}_2) - t_{\alpha, n_1+n_2-2}\, S_p\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}$

Case-II:- $\sigma_1^2 \ne \sigma_2^2$ (Behren's-fisher Problem)

(a) $(\bar{x}_1-\bar{x}_2) - t_{\alpha/2, \nu}\sqrt{\frac{S_1^2}{n_1}+\frac{S_2^2}{n_2}} \le (\mu_1-\mu_2) \le (\bar{x}_1-\bar{x}_2) + t_{\alpha/2, \nu}\sqrt{\frac{S_1^2}{n_1}+\frac{S_2^2}{n_2}}$

(b) $\mu_1-\mu_2 \le (\bar{x}_1-\bar{x}_2) + t_{\alpha, \nu}\sqrt{\frac{S_1^2}{n_1}+\frac{S_2^2}{n_2}}$

(c) $(\mu_1-\mu_2) \ge (\bar{x}_1-\bar{x}_2) - t_{\alpha, \nu}\sqrt{\frac{S_1^2}{n_1}+\frac{S_2^2}{n_2}}$

where,

$$\nu = \frac{\left(S_1^2/n_1 + S_2^2/n_2\right)^2}{\dfrac{\left(\frac{S_1^2}{n_1}\right)^2}{(n_1-1)} + \dfrac{\left(S_2^2/n_2\right)^2}{(n_2-1)}}$$

6 ON Ratio of Variances of Two Normal Distribution: (F-distributⁿ)

(a) $\frac{S_1^2}{S_2^2} F_{1-\alpha/2, n_2-1, n_1-1} \le \frac{\sigma_1^2}{\sigma_2^2} \le \frac{S_1^2}{S_2^2} F_{\alpha/2, n_2-1, n_1-1}$

(b) $\frac{\sigma_1^2}{\sigma_2^2} \le \frac{S_1^2}{S_2^2} F_{\alpha/2, n_2-1, n_1-1}$

(c) $\frac{\sigma_1^2}{\sigma_2^2} \ge \frac{S_1^2}{S_2^2} F_{1-\alpha/2, n_2-1, n_1-1}$

$\frac{S_1^2}{S_2^2} \times \frac{1}{F_{\alpha/2, n_1-1, n_2-1}} \le \frac{\sigma_1^2}{\sigma_2^2} \le \frac{S_1^2}{S_2^2} \times \overset{F_{\alpha/2, n_2-1, n_1-1}}{\uparrow}$

$F_{1-\alpha/2, \nu_2, \nu_1} = \frac{1}{F_{\alpha/2, \nu_1, \nu_2}}$

7 ON Binomial Parameters:- (Normal Distribut")

(a) $\hat{p} - Z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \le p \le \hat{p} + Z_{\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$ (a) (if n is large and $p \geq 0.1$, Normal dist" approximat")

(b) if n is large and p is small, then poission Approximat" is useful to construct interval for Binomial.

(c) for small n Binomial table should be used.

8 ON Difference b/w two Binomial Proportion's:-

(a) $(\hat{P}_1 - \hat{P}_2) - Z_{\alpha/2}\sqrt{\frac{\hat{P}_1(1-\hat{P}_1)}{n_1} + \frac{\hat{P}_2(1-\hat{P}_2)}{n_2}} \le (P_1 - P_2) \le (\hat{P}_1 - \hat{P}_2) + Z_{\alpha/2}\sqrt{\frac{\hat{P}_1(1-\hat{P}_1)}{n_1} + \frac{\hat{P}_2(1-\hat{P}_2)}{n_2}}$

Same rule's as above for using distribut".

———— × ————

~~Hypothesis Testing~~:-

P-Value:- Smallest level of significance that would lead to rejection of the null Hypothesis. i.e if P-value is less than (α) it (H_0) would be rejected.

($\alpha \geq P \to$ for reject" of H_0)

For Normal Distribut" -

$$P = \begin{cases} 2(1-\Phi(|z_0|)) & \to \text{for two tailed} \quad H_0: \mu = \mu_0 \quad H_1: \mu \neq \mu_0 \\ 1-\Phi(z_0) & \to \text{for an upper tailed test} \quad H_0: \mu = \mu_0 \quad H_1: \mu > \mu_0 \\ \Phi(z_0) & \to \text{for a lower-tailed test} \quad H_0: \mu = \mu_0 \quad H_1: \mu < \mu_0 \end{cases}$$