QC REPORT

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Some Sample Size Questions and Answers

(Don Holmes)

Questions about sample size required to achieve some desired level of accuracy arise very often. There are a rather wide variety of these questions. Examples include (you may have others - let us know):

Question # 1: How large a sample do I need to estimate the average value of my process?

Question # 2: **What sample size do I need to decide whether or not to accept a lot?**

Question # 3: How large a sample do I need from a lot generated by a multiple stream process to be confident that the sample includes an item from each stream?

I'll discuss these sample size questions (and others, if you send them) in separate QC Reports. Question #1 was discussed in December '96 QC Report. Please call Stochos if you would like to obtain a copy.

Several Definitions:

n = Sample size

μ = Process average - a measure of process center

$\overline{X}$ = sample estimate of process average is defined as:

$\overline{X}$ = Sum (x)/n *example:* data x's 1, 2, 3, 4, 5

$\overline{X}$ = (1 + 2 + 3 + 4 + 5)/5 = 3

σ (Sigma) = Process standard deviation - a measure of process variability

Sample estimate of process standard deviation is defined as:

s = Square root (Sum ((x - $\overline{X}$)^2) / (n-1))

example: data x 1, 2, 3, 4, 5 $\overline{X}$ =3

x - $\overline{X}$ -2,-1, 0, 1, 2

(x - $\overline{X}$)^2 4, 1, 0, 1, 4 sum ((x - $\overline{X}$)^2) = 10

sample standard deviation = Sqr (10/4) = 1.58

Z(x) = The number of standard deviations an x value is from the average.

Z(x) = (x-μ)/σ *example:* mu = 50, sigma = 2, x = 53

z (53) = (53 - 50)/2 = 1.5 (53 is one and one half standard deviations away from 50)

For a Normal curve, 99.7% of the X's are within 3 standard deviations of the average, 95% are within 2 standard deviations etc. So Z = 2 is associated with "95% confidence". Other confidence percentages can be found in textbooks on statistics or using Custom/QC's Frequency Curve module.

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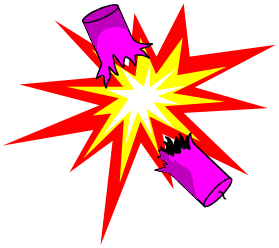

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SLED consists of five (5) programs

DESIGN: Optimizing processes, product specifications and preventing defects require that cause-and-effect relationships be defined. This necessitates the planning and conduct of experiments. Full factorial designs are widely acknowledged as effective solutions for systems that involve several factors. When the number of factors exceeds four, however, the cost of full factorials, and the time to run them may become prohibitive. To overcome these drawbacks, designs known as fractional factorial designs have been developed. The DESIGN program compiles Sequence-Leveled Experimental Designs (SLED), a significant break-through. This program provides balanced, randomized experimental programs for up to twenty suspected factors and minimizes the number of tests required. Each factor may have up to ten levels, and all first order interactions will be uniquely identified (without confounding!).

REGRES: A step-wise multiple regression program, REGRES is useful in both simple and multiple correlation problems. Where it is necessary to approximate relationships between various factors and quality characteristics, five hundred data points and thirty variables may be input. Such mathematical transformations as addition, subtraction, multiplication and division; converting to logarithms and the use of constants are all possible. REGRES can also run multiple outputs with a single programming.

INTERACT: Working from a REGRES data file, INTERACT sorts the dependent variables - one run each - into the appropriate two-factor interactions. A visual assessment of the data will suggest whether or not it is advisable to run an analysis of variance to determine how significant an interaction may be.

ANOV2: This program performs the analysis of variance for up to five factors and ten levels of any factor. It allows pooling effects for handling replications, nested factors and the like. It also permits labeling the sources of variation and presenting them in any desired array.

REFINE: In discovering optimal solutions to quality problems, it is often required that all quality characteristics, including cost, be combined in one framework so that the best result is apparent. REFINE allows quick comparisons and discovery of that particular combination which satisfies all quality requirements at minimum cost.

Sample Question #2:

Cont'd from page 1

What sample size should I use to decide whether or not to accept a lot of material?

Here we must look at several conditions to arrive at the answers to this question. These conditions are discussed following the equations to be used. The procedure is to take a sample of size n (Equation 2) and calculate $\overline{x}$. If the sample $\overline{x}$ exceeds Xbarcrit (Equation 3) then reject the lot. (I'm assuming an upper value for the process average that should not be exceeded.)

Solution: n = ((Za + Zr)* σ) / (μ(a) - μ(r))^2 (2)

Xbarcrit = (Za*μ (r) + Zr*μ(a)^2 / (Za + Zr)^2 (3)

Example: Suppose you would like to accept a process whose true average value (μ(a) is 50 (good process)) about 95% of the time but accept a process whose true value μ(r) is 52 (bad process) only about 2.5% of the time.

Since $\overline{x}$ values are distributed approximately as a Normal distribution, we have the following results:

To have μ(a) = 50 accepted 95% of the time, Za = 1.65

To have μ(r) = 52 accepted at most 2.5% of the time, Zr = -1.96 (Notice z is negative since the critical value of $\overline{x}$ will be below μ(r)).

Assume σ = 2

n = ((1.65+1.96)*2)^2 / (50-52)^2 = 51.83/4 = 13

Xbarcrit = (1.65*52+1.96*50)/(1.65+1.96)
= 183.80/3.61 = 50.97

Procedure: Take a sample of size 13. If the $\overline{x}$ from the sample is greater than 50.97, reject the lot (or setup). If $\overline{x}$ from the sample is less than 50.97, then accept the lot (or setup).

Notes: If you do not know σ (sigma): put your sample estimate of the standard deviation in equation two and recalculate the sample size. If the new sample size is less than or equal to the first one, you're finished – make your Accept or Reject decision.

If the new sample size is larger than the one you used, take more samples to bring the total samples to the new value and repeat the calculations.

If you are concerned with a process average that is too low, rather than too high, use the same formulas, but the Z's are reversed.