

Iterations

Reliability, Confidence, and Sample Size

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Say I have designed a widget that is supposed to survive N cycles of stress S applied at frequency f .

I can demonstrate that the widgets will conform to the performance requirement by manufacturing a set of them and testing them. Such testing, though, runs headlong into the question of sample size. How many widgets should I test?

For starters, however many widgets I choose to test, I would want all of them to survive i.e. the number of failures, c , in my sample, n , should be zero. (The reason for this has more to do with the psychology of perception than statistics.)

If I get zero failures ($c = 0$) in 30 samples ($n = 30$), does that mean I have perfect quality relative to my requirement? No, because the sample failure rate, $p = 0/30$ or 0%, is a point estimate for the population failure rate, p' . If I took a different sample of 30 widgets from the same population, I may get one, two, or more failures.

The sample failure rate, p , is the probability of failure for a single widget as calculated from test data. It is a statistic. It estimates the population parameter, p' , which is the theoretical probability of failure for a single widget. The probability of failure for a single widget tells us how likely it is to fail the specified test.

If we know the likelihood of a widget failing the test, p' , then we also know the likelihood of it surviving the test, $q' = (1 - p')$. The value, q' , is also known as the reliability of the widget. It is the probability that a widget will perform its intended function under stated conditions for the specified interval.

The likelihood of finding c failures in n samples from a stable process with p' failure rate is given by the binomial formula.

$$P(c) = C \binom{n}{c} (p')^c (q')^{n-c}$$

But here I am interested in just the case where I find zero failures in n samples. What is the likelihood of me finding zero failures in n samples for a production process with p' failure rate?

$$P(0) = C \binom{n}{0} (p')^0 (q')^{n-0}$$

$$P(0) = (q')^n$$

$$P(0) = (1 - p')^n$$

If I know the likelihood of finding zero failure in n samples from a production process with p' failure rate, then I know the likelihood of finding 1 or more failures in n samples from the production process, too. It is $P(c \geq 1) = 1 - P(0)$. This is the confidence with which I can say that the failure rate of the production process is no worse than p' .

Usually a lower limit is specified for the reliability of the widget. For example, I might want the widget to survive the test at least 95% of the time or $q' = 0.95$. This is the same as saying I want the failure rate to be no more than $p' = 0.05$.

I would also want to have high confidence in this minimum reliability (or maximum failure rate). For example, I might require 90% confidence that the minimum reliability of the widget is $q' = 0.95$.

A 90% confidence that the reliability is at least 95% is the same as saying 9 out of 10 times I will find one or more failures, c , in my sample, n , if the reliability were less than or equal to 95%. This is also the same as saying that 1 out of 10 times I will find zero failures, c , in my sample, n , if the reliability were less than or equal to 95%. This, in turn, is the same as saying $P(0) = 10\%$ or 0.1 for $p' = 0.05$.

With $P(0)$ and p' defined, I can calculate the sample size, n , that will satisfy these requirements.

$$P(0) = (1 - p')^n$$

$$\ln(P(0)) = n * \ln((1 - p'))$$

$$n = \frac{\ln(P(0))}{\ln(1 - p')}$$

The formula can be used to calculate the sample size for specific values of minimum reliability and confidence level. However, there are standard minimum reliability and confidence level values used in industry. The table below provides the sample sizes with no failures for some standard values of minimum reliability and confidence level.

Minimum Reliability (1 - p')	Confidence Level (1 - P(0))			
	0.90	0.95	0.98	0.99
0.998	1150	1496	1954	2300
0.995	459	598	780	919
0.990	229	298	389	458
0.950	45	58	76	90
0.900	22	28	37	44

What should the reliability of the widget be? That depends on how critical its function is.

What confidence level should you choose? That again depends on how sure you need to be about the reliability of the widget.

Note: A basic assumption of this method is that the failure rate, p' , is constant for all the widgets being tested. This is only possible if the production process producing these widgets is in control. If this cannot be

demonstrated, then this method will not help you establish the minimum reliability for your widget with any degree of confidence.

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