X-bar and R and X-bar and S Charts

For some processes, more than one item can be measured at a time. For example, once an hour, five consecutive items off the line are measured. Because these items are close together in time, they form natural, or rational, subgroups.

Data from rational subgroups can be plotted on an X-bar and R chart or an X-bar and S chart. The subgroup means are plotted on an X-bar chart. We use this chart to monitor subgroup means over time. The center line on the X-bar chart is the average of the subgroup means, or the grand mean. This is written X-bar-bar.

Because we use sample means, we place the control limits at plus or minus 3 standard errors of the mean. The subgroup ranges or standard deviations are plotted on a second chart, either an R (or range) chart or an S (or standard deviation) chart. This chart monitors within-subgroup variability over time.

Here, we calculate the range for the first subgroup and plot this on the R chart. We use the average range to estimate the within-subgroup standard deviation. We then use this estimate to calculate the control limits for the X-bar chart.

Let's consider an example. You are on a team charged with improving the dimensional conformance of a small metal part. The critical measurement is the thickness of the part. Your goals are to bring the thickness to target and to reduce variability.

The target is 40 plus or minus 5 hundredths of an inch (which is about 1 centimeter). One of your first steps is to collect some baseline data and construct a control chart to study process variation. You measure subgroups of five consecutive parts every hour for 25 hours.

Here are the X-bar and R charts and control limit summaries. Together, the two charts characterize the spread and centering of thickness over time.

When you run the tests for special causes, you see that the process is stable. That is, there are no special causes. This is good. This means that the process is in control, and that future performance is predictable.

Let's look at the overall process mean. The grand mean, 41.328, is above the target of 40. So although the process is stable, the process mean is not on target.

What about the thickness of individual parts? Your specifications for the process are 40 plus or minus 5, or 35 to 45 hundredths of an inch.

X-bar charts are used to plot subgroup means, and the upper and lower control limits provide a range of values for subgroup means. Specifications, on the other hand, relate to individual measurements. Specification limits are the range of acceptable values for individual measurements. You can't compare specification limits to control limits on X-bar charts. For this reason, specification limits should not be drawn on X-bar charts. But this question of whether a process is meeting specifications is important. In the next lesson, you learn about process capability studies, which we use to address this question.

Let's return to our example. Why did we use subgroup ranges rather than subgroup standard deviations? X-bar and R charts are commonly used for historical purposes. Remember that, in the past, control charts were constructed by hand. It's much easier to calculate the subgroup ranges by hand than it is to calculate standard deviations.

Now that we have computers to do the work for us, it might make more sense to use the standard deviation instead of the range as the measure of within-subgroup variability. But many still use the range for its simplicity and ease of understanding.

In this video, you've learned how to construct and interpret X-bar and R charts. In the next video, you see how to construct both X-bar and R charts and X-bar and S charts in JMP.

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