Control Chart Rules and Interpretation

Control charts are a valuable tool for monitoring process performance. However, you have to be able to interpret the control chart for it to be of any value to you. Is communication important in your life? Of course it is – both at work and at home. Here is the key to effectively using control charts – ***the control chart is the way the process communicates with you***. Through the control chart, the process will let you know if everything is "under control" or if there is a problem present. Potential problems include large or small shifts, upward or downward trends, points alternating up or down over time and the presence of mixtures.

This month's publication examines 8 rules that you can use to help you interpret what your control chart is communicating to you. These rules help you identify when the variation on your control chart is no longer random, but forms a pattern that is described by one or more of these eight rules. These patterns give you insights into what may be causing the "special causes" – the problem in your process.

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Variation Review

We have covered variation in 11 publications over the years. Here is an excerpt from one:

"I used to, now and then, spill a glass of milk when I was young. Our table slanted toward where my mother sat. So, the milk always headed in her direction. And she usually had some choice words when this happened. Of course, I was at fault. I needed to be more careful. Or was that really true? If you understand variation, you will realize that most of the problems you face are not due to individual people, but to the process -- the way it was designed and the way it is managed on a day-to-day basis.

Variation comes from two sources, common and special causes. Think about how long it takes you to get to work in the morning. Maybe it takes you 30 minutes on average. Some days it may take a little longer, some days a little shorter. But as long as you are within a certain range, you are not concerned. The range may be from 25 to 35 minutes. This variation represents common cause variation --- it is the variation that is always present in the process. And this type of variation is consistent and predictable. You don't know how long it will take to get to work tomorrow, but you know that it will be between 25 and 35 minutes as long as the process remains the same.

Now, suppose you have a flat tire when driving to work. How long will it take you to get to work? Definitely longer than the 25 to 35 minutes in your "normal" variation. Maybe it takes you an hour longer. This is a special cause of variation. Something is different. Something happened that was not supposed to happen. It is not part of the normal process. Special causes are not predictable and are sporadic in nature.

Why is it important to know the type of variation present in your process? Because the action you take to improve your process depends on the type of variation present. If special causes are present, you must find the cause of the problem and then eliminate it from ever coming back, if possible. This is usually the responsibility of the person closest to the process. If only common causes are present, you must FUNDAMENTALLY change the process. The key word is fundamentally -- a major change in the process is required to reduce common causes of variation. And management is responsible for changing the process.

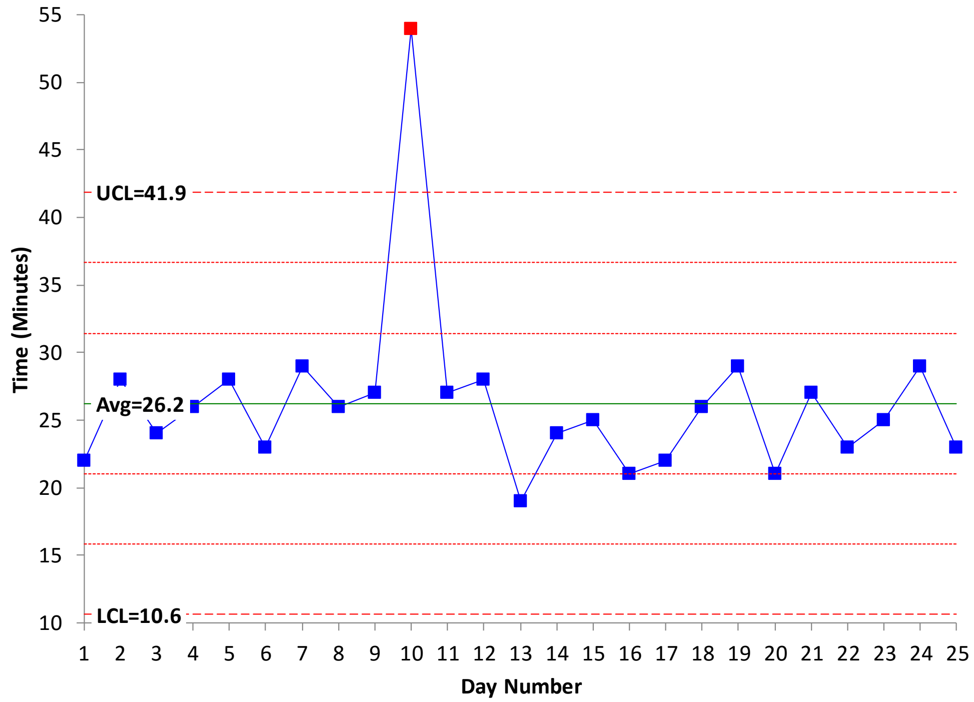
It has been estimated that 94% of the problems a company faces are due to common causes. Only 6% are due to special causes (that may or may not be people related). So, if you always blame problems on people, you will be wrong at least 85% of the time. It is the process most of the time that needs to be changed. Management must set up the system to allow the processes to be changed."

Control Chart Review

The only effective way to separate common causes from special causes of variation is through the use of control charts. A control chart monitors a process variable over time – e.g., the time to get to work. The average is calculated after you have sufficient data. The control limits are calculated – an upper control limit (UCL) and a lower control limit (LCL). The UCL is the largest value you would expect from a process with just common causes of variation present. The LCL is the smallest value you would expect with just common cause of variation present. As long as the all the points are within the limits and there are no patterns, only common causes of variation are present. The process is said to be "in control."

Figure 1 is an example of a control chart using the driving to work example. Each day the time to get to work is measured. The data are then plotted on the control chart. The average is calculated. The average is 26.2 – which means it takes on average each day 26.2 minutes to get to work. The control limits are then calculated. The UCL is 41.9 minutes. This is the maximum time it will take to get to work when only common causes are present. The LCL is 10.6 minutes. This is the minimum time it will take to get to work when only common causes are present. As long as all the points are within the control limits and there are no patterns, then process is in statistical control.

Figure 1: Control Chart Example



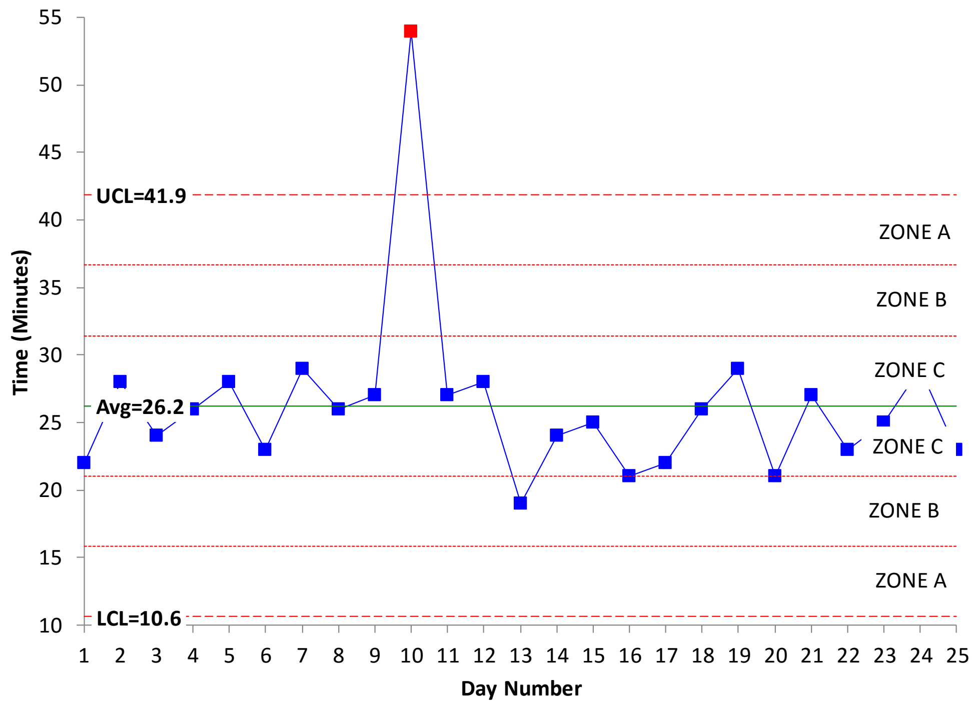
There is one point beyond the UCL in Figure 1. This is the first pattern that signifies an out of control point – a special cause of variation. One possible cause is the flat tire. There are many other possible causes as well – car break down, bad weather, etc.

Special causes of variation are detected on control charts by noticing certain types of patterns that appear on the control chart. The point beyond the control limits is one such pattern. You might see a pattern of 7 consecutive points above the average. This pattern indicates that something has happened to cause your process average go up – a special cause is present. Recognizing patterns – and what they mean in your process – is one key to finding the reason for special causes. All of the control chart rules are patterns that form on your control chart to indicate special causes of variation are present.

Some of these patterns depend on "zones" in a control chart. To see if these patterns exits, a control chart is divided into three equal zones above and below the average. This is shown in Figure 2.

Zone C is the zone closest to the average. It represents the area from the average to one sigma above the average. There is a corresponding zone C below the average. Zone B is the zone from one sigma to two sigma above the average. Again, there is a corresponding Zone B below the average. Zone A is the zone from two sigma to three sigma above the average – as well as below the average.

Figure 2: Control Chart Divided into Zones



The 8 Control Chart Rules

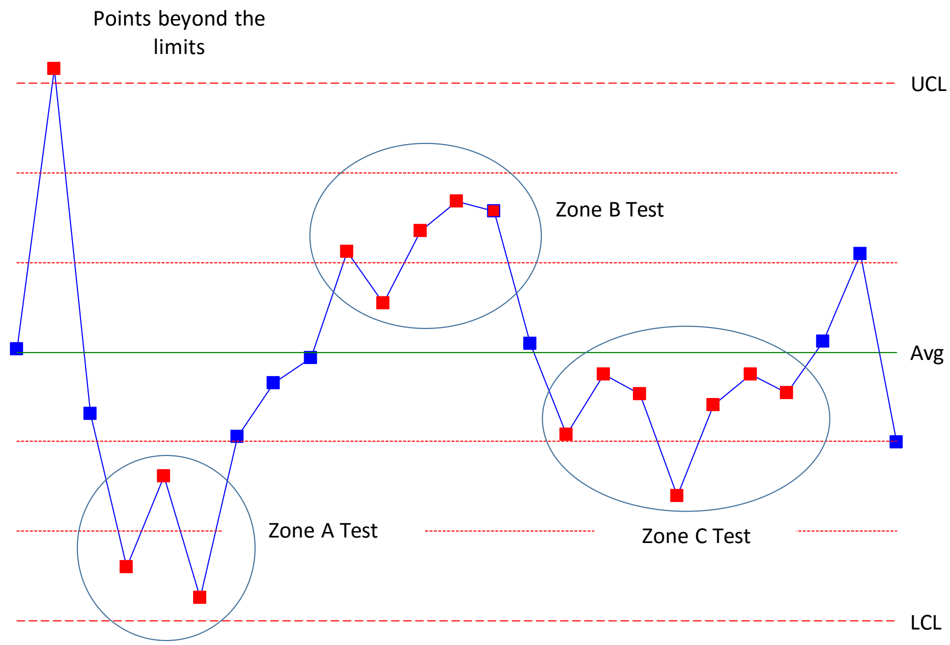
If a process is in statistical control, most of the points will be near the average, some will be closer to the control limits and no points will be beyond the control limits. The 8 control chart rules listed in Table 1 give you indications that there are special causes of variation present. Again, these represent patterns.

Table 1: Control Chart Rules

Rule	Rule Name	Pattern
1	Beyond Limits	One or more points beyond the control limits
2	Zone A	2 out of 3 consecutive points in Zone A or beyond
3	Zone B	4 out of 5 consecutive points in Zone B or beyond
4	Zone C	7 or more consecutive points on one side of the average (in Zone C or beyond)
5	Trend	7 consecutive points trending up or trending down
6	Mixture	8 consecutive points with no points in Zone C
7	Stratification	15 consecutive points in Zone C
8	Over-control	14 consecutive points alternating up and down

It should be noted that the numbers can be different depending upon the source. For example, some sources will use 8 consecutive points on one side of the average (Zone C test) instead of the 7 shown in the table above. But they are all very similar. Figures 3 through 5 illustrate the patterns. Figure 3 shows the patterns for Rules 1 to 4.

Figure 3: Zone Tests (Rules 1 to 4)



Rules 1 (points beyond the control limits) and 2 (zone A test) represent sudden, large shifts from the average. These are often fleeting – a one-time occurrence of a special cause – like the flat tire when driving to work.

Rules 3 (zone B) and 4 (Zone C) represent smaller shifts that are maintained over time. A change in raw material could cause these smaller shifts. The key is that the shifts are maintained over time – at least over a longer time frame than Rules 1 and 2.

Figure 4 shows Rules 5 and 6. Rule 5 (trending up or trending down) represents a process that is trending in one direction. For example, tool wearing could cause this type of trend. Rule 6 (mixture) occurs when you have more than one process present and are sampling each process by itself. Hence the mixture term. For example, you might be taking data from four different shifts. Shifts 1 and 2 operate at a different average than shifts 3 and 4. The control chart could have shifts 1 and 2 in zone B or beyond above the average and shifts 3 and 4 in zone B below the average – with nothing in zone C.

Figure 5 shows rules 7 and 8. Rule 7 (stratification) also occurs when you have multiple processes but you are including all the processes in a subgroup. This can lead to the data "hugging" the average – all the points in zone C with no points beyond zone C. Rule 8 (over-control) is often due to over adjustment. This is often called "tampering" with the process. Adjusting a process that is in statistical control actually increases the process variation. For example, an operator is trying to hit a certain value. If the result is above that value, the operator makes an adjustment to lower the value. If the result is below that value, the operator makes an adjust to raise the value. This results in a saw-tooth pattern.

Figure 4: Rules 5 and 6

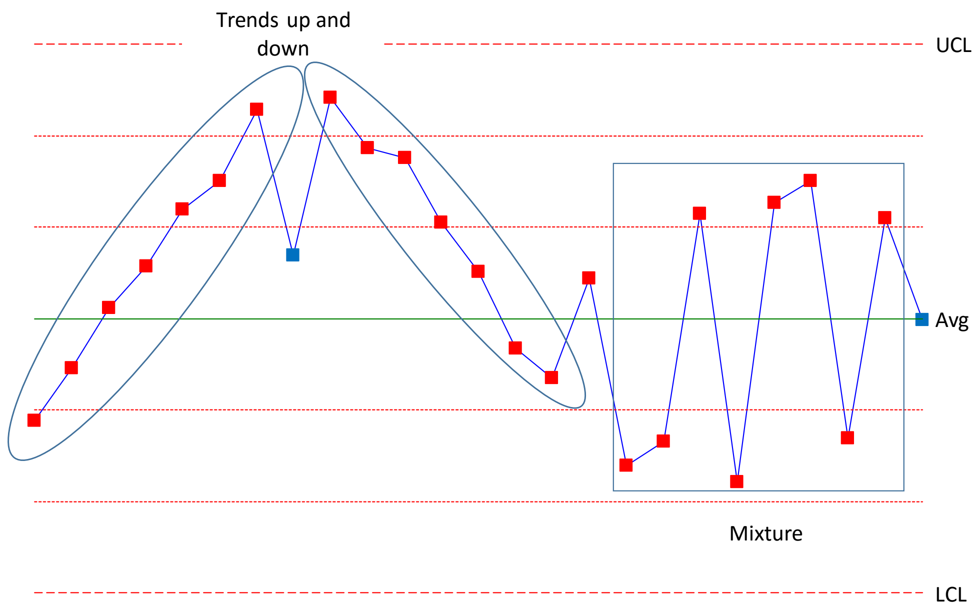
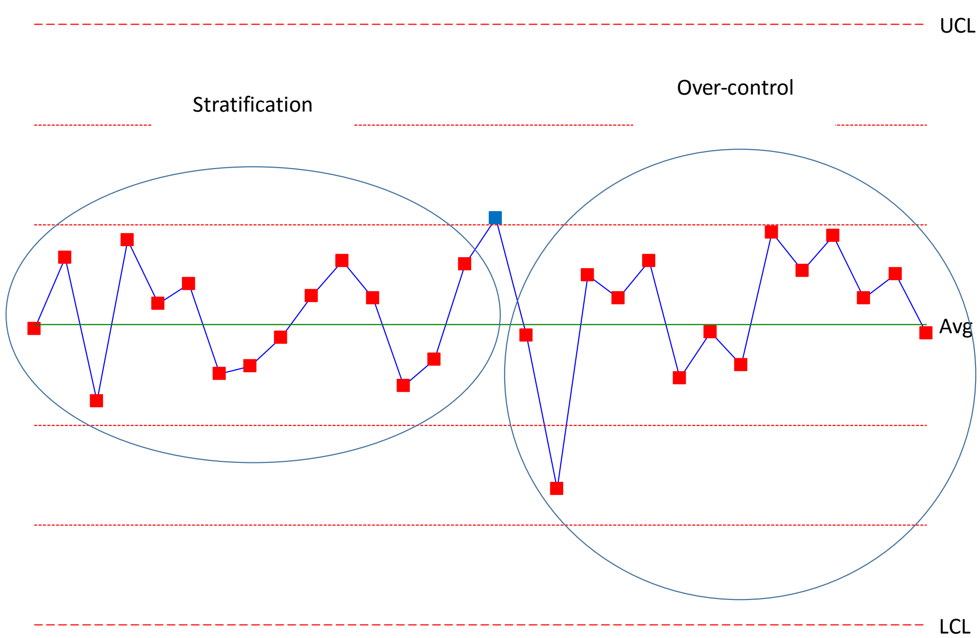


Figure 5: Rules 7 and 8



Rules 6 and 7, in particular, often occur because of the way the data are subgrouped. Rational subgrouping is an important part of setting up an effective control chart. A previous publication demonstrates how mixture and stratification can occur based on the subgrouping selected. These rules represent different situations – patterns = on a control chart. It should be noted that not all rules apply to all types of control charts. Table 2 summaries the rules by the type of pattern.

Table 2: Rules by Type of Pattern

Pattern Description	Rules
Large shifts from the average	1, 2
Small shifts from the average	3, 4
Trends	5
Mixtures	6
Stratifications	7
Over-control	8

Possible Causes by Pattern

It is difficult to list possible causes for each pattern because special causes (just like common causes) are very dependent on the type of process. Manufacturing processes have different issues that service processes. Different types of control chart look at different sources of variation. Still, it is helpful to show some possible causes by pattern description. Table 3 attempts to do this based on the type of pattern.

Table 3: Possible Causes by Pattern

Pattern Description	Rules	Possible Causes
Large shifts from the average	1, 2	New person doing the job Wrong setup Measurement error Process step skipped Process step not completed Power failure Equipment breakdown
Small shifts from the average	3, 4	Raw material change Change in work instruction Different measurement device/calibration Different shift Person gains greater skills in doing the job Change in maintenance program Change in setup procedure
Trends	5	Tooling wear Temperature effects (cooling, heating)
Mixtures	6	More than one process present (e.g. shifts, machines, raw material.)
Stratifications	7	More than one process present (e.g. shifts, machines, raw materials)
Over-control	8	Tampering by operator Alternating raw materials

Table 3 provides some guidance on what you should be thinking about as you try to find the reasons for special causes. For example, if Rule 1 or Rule 2 is violated, you should be asking "what in this process could cause a large shift from the average?". Or if Rule 6 occurs, you should be asking "what in this process could cause there to be more than one process present?" These type of questions can help guide brainstorming sessions to find the reasons for the special cause of variation. The type of pattern can guide your analysis of the out of control point.

Summary

This publication took a look at the 8 control chart rules for identifying the presence of a special cause of variation. The rules describe certain patterns of variation that will give you insights on where to look for the special cause of variation. No one table can give you the reasons for out of control points in your process. You have to use your own knowledge (and that of those closest to the process) to discover the reason.

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Thanks so much for reading our publication. We hope you find it informative and useful. Happy charting and may the data always support your position.

Sincerely,

Dr. Bill McNeese
BPI Consulting, LLC