Homogeneity Charts

The fourth of six uses

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The question "Is this batch like the others?" is asked all over the world on a daily basis. It turns out that the process behavior chart provides a very effective answer for questions about the homogeneity of the product stream.

In World War II General Leslie Simon used the process behavior chart to define "grand lots" of material. Material in the same grand lot should all be treated alike, but material belonging to different grand lots might need to be treated differently.

An example of this concept comes from an automotive supplier making hydraulic brake hose. This hose consists of a rubber tube, surrounded by a reinforcing braided tube of synthetic fiber, and covered by an outer layer of rubber. The government specification for the minimum tensile strength for the synthetic fiber is 5.0 pounds. The automobile company required a minimum tensile standard of 5.5 pounds. And the automotive supplier had a more conservative internal minimum standard tensile of 6.0 pounds. (A burst brake hose can have serious consequences.)

Shipment	-1-	-2-	-3-	-4-	-5-
Tensiles	8.7	8.8	9.0	9.4	9.1
	9.6	9.2	8.4	8.3	9.7
	9.7	9.2	8.6	8.7	9.0
	8.5	9.3	8.5	8.3	8.2
	8.7	8.5	9.8	8.7	9.5
	8.7	9.5	8.7	9.6	8.1
Averages	8.98	9.08	8.83	8.83	8.93
Ranges	1.2	1.0	1.4	1.3	1.6

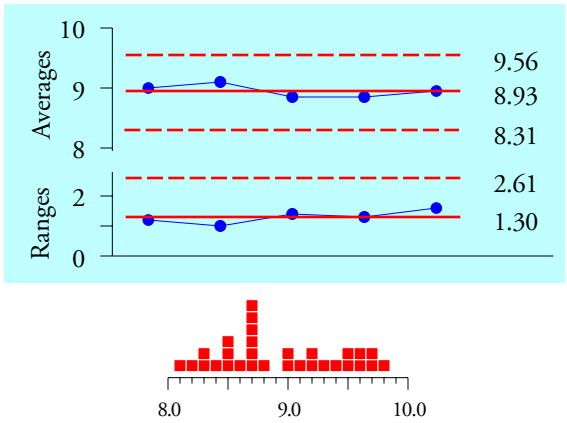

Figure 1: Tensile Strengths for Shipments 1 to 5

The automotive supplier received shipments of the synthetic fiber from a single chemical company. They opened each shipment, cut a sample from the end of each of the six spools, and

tested it for tensile strength. The homogeneity chart and histogram for the tensile strengths for five successive shipments are shown in Figure 1. The limits for this homogeneity chart were based on these five shipments. Clearly, these five shipments are all part of the same grand lot, and with average tensile strengths in the neighborhood of nine pounds there is no problem with meeting the minimum specification.

As subsequent shipments arrived they were subjected to the same incoming testing. The data for each shipment was used to add a point to the average and range chart. Shipments 6, 7, 8, 9, and 10 were all part of the same grand lot as shipments 1 through 5. They had similar test values and should perform in a similar manner both in production and in the field.

However, shipment 11 was not the same as shipments 1 through 10. This shipment clearly had lower tensile strengths than the other shipments. Based on the fact that shipment 11 was not part of the same grand lot as the prior shipments the automotive supplier rejected shipment 11.

Shipment	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-	-10-	-11-
Tensiles	8.7	8.8	9.0	9.4	9.1	8.9	9.5	9.3	9.3	9.1	7.2
	9.6	9.2	8.4	8.3	9.7	10.4	8.6	8.8	9.2	9.3	6.6
	9.7	9.2	8.6	8.7	9.0	8.7	9.3	8.5	8.4	8.4	7.3
	8.5	9.3	8.5	8.3	8.2	9.7	7.7	7.6	8.7	8.7	6.4
	8.7	8.5	9.8	8.7	9.5	8.9	8.6	9.1	10.0	8.8	6.6
	8.7	9.5	8.7	9.6	8.1	9.6	9.0	9.1	9.6	9.0	6.4
Averages	8.98	9.08	8.83	8.83	8.93	9.37	8.78	8.73	9.20	8.88	6.78
Ranges	1.2	1.0	1.4	1.3	1.6	1.7	1.8	1.7	1.6	0.9	1.1

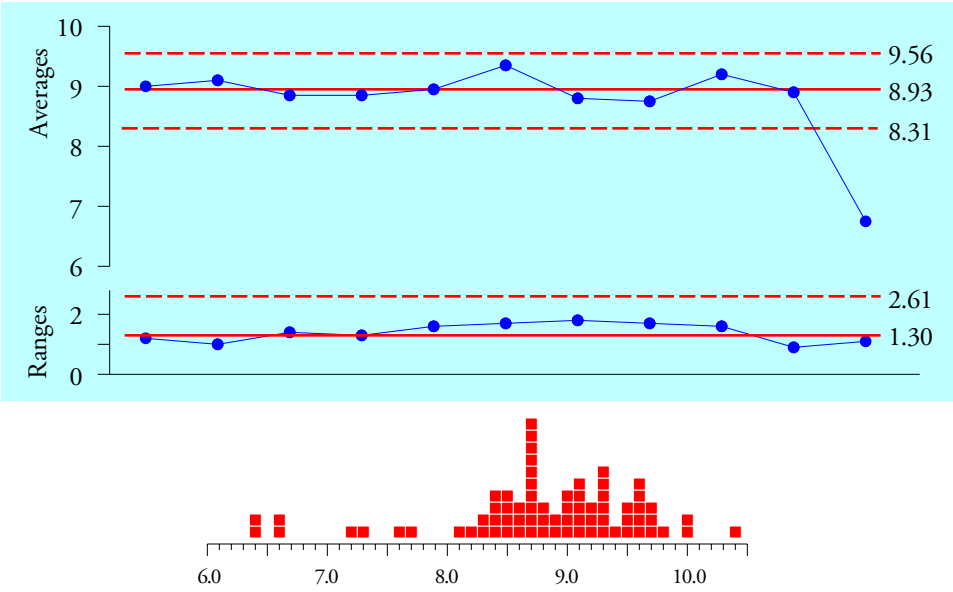

Figure 2: Tensile Strengths for Shipments 1 to 11

Of course the chemical company objected. "Each sample from Shipment 11 met the customer specification of 6.0 pounds minimum tensile." The customer responded that shipment 11 was clearly different from what they had been using to make brake hoses. They insisted that the supplier take the shipment back. Every time that the supplier protested that the product was in spec, the customer simply showed them the chart in Figure 2 and said that shipment 11 was not like the others.

"We know from experience that the other shipments made good brake hose. We cannot be sure about shipment 11. If we use shipment 11 and we get sued because something goes wrong, we will not have any excuse when we have to produce our inspection records in court. We would have knowingly produced brake hose with a shipment that we knew had lower tensile strength."

Finally, after three days of negotiation with the supplier, the customer said that they would accept shipment 11 if the supplier would be willing to accept any and all liability that arose from brake hoses produced from shipment 11. At that point the supplier decided to take the shipment back, even though it met everyone's specifications. In his summary memo he product specialist from the chemical company asked "What are we going to do to fight this SPC thing?" It was going to make the job of talking the customer into using marginal product much harder.

HOMOGENEITY CHARTS

While it might be said that all process behavior charts are homogeneity charts, I use this terminology to distinguish this usage from other uses. With a report card chart the emphasis is upon visualizing the overall operation and understanding the noise inherent in our report-card measures. With a process monitor chart the emphasis is upon making adjustments to maintain the status quo. With a process trial chart the emphasis is upon evaluating deliberate process changes. With a homogeneity chart the emphasis is upon the similarity of a sequence of lots or shipments or batches using outgoing or incoming quality assurance data. In one sense this is very much like a report-card chart in that it may be too late to take any corrective action on the process, but unlike many report-card charts, homogeneity charts tend to be focused on specific products rather than dealing with highly aggregated metrics.

A company used one tanker load of a certain chemical compound each month. Each load was analyzed and the key ingredients were tracked on separate homogeneity charts. The chart for one of these ingredients is shown in Figure 3. When the customer asked the supplier what they had changed about their process in November all they got were denials. The supplier claimed the process was unchanged. In response, the customer simply handed the suppler the homogeneity chart in Figure 3 and said that it would be a shame if they knew more about the supplier's process than the supplier did. Something had clearly changed in November, whether or not the supplier knew about it.

After being confronted with the chart in Figure 3, the supplier admitted to having made a process change in November. However, the fact that they had done so was considered proprietary information. This change was supposed to be a closely held secret. Since the new product met the same specifications as the old product they had not notified their customers of the change. Unfortunately, just because the new product met the same specifications as the prior product did not mean that it was the same as the old product, or that is was going to react the same way in the customer's process.

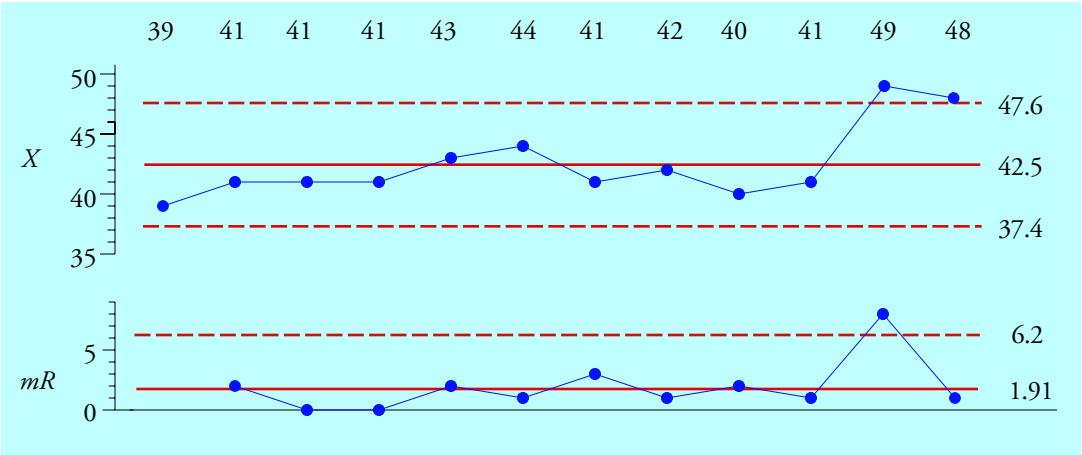

Figure 3: Analysis of Compound 3 in Monthly Rail Car-loads

HOW MANY DATA

According to Shewhart, when using an average and range chart, you may compute limits for your homogeneity chart with as few as two subgroups of size four. If the product stream is changing you will detect it soon enough. If the product stream is not changing, then every window on the process will look very much like every other window. So you do not need to wait until you have a lot of data to compute limits.

If you are using individual values on a homogeneity chart, and you have fewer than five data, you may use your data to compute limits to use to assess the homogeneity of future values, but you will be hard pressed to detect any lack of homogeneity among the five or fewer values in your baseline. So baselines of five or fewer values allow you to check to see if *future* values are homogeneous with the baseline values, but they do not provide a way to check the five or fewer baseline values for *internal* homogeneity.

Before a homogeneity chart based on individual values can be used both as a check for the internal homogeneity of the baseline values and also for the homogeneity of future values you will need to have at least eight or nine values in the baseline. (All of these limitations are imposed by the arithmetic and cannot be avoided.) However, by the way we organize our computations we can ask specific questions using homogeneity charts even when we have very few data.

An example of this comes from Shewhart who reported on comparisons between the Imperial Standard Yard (ISY) and Parliamentary Copy No. 5 (PC5) made in 1852, 1876, 1892, 1912, 1922, and 1932. The observed differences, ISY – PC5, in millionths of an inch, were reported as: –55, –33, 70, –43, –23, and –47. Right off the bat, the 1892 value of 70 millionths looks suspicious. So let us consider if it is consistent with the other five determinations. We use the other five determinations of ISY – PC5 to compute an average of –40.2 millionths and an average moving range of 19 millionths, and get the homogeneity chart in Figure 4. Clearly the 1892 comparison is not consistent with the other five comparisons. (I suspect they simply transposed the order and recorded PC5 – ISY since a reading of minus 70 would be consistent with the other five readings.)

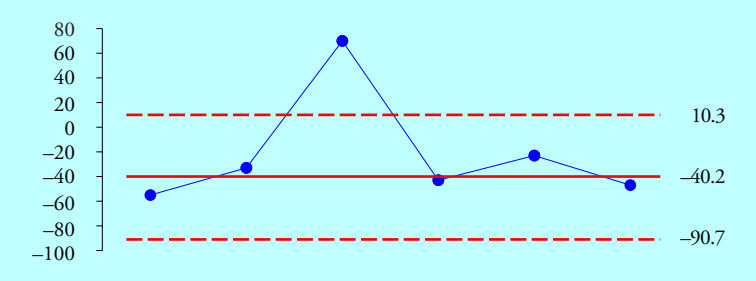

Figure 4: Homogeneity Chart for Comparisons Between ISY and PC5

So even though you may not be able to adjust the process, and even though you may not be trying to assess a deliberate process change, you may still use the process behavior chart to assess the homogeneity of a stream of values that ought to he similar. Because when one of these things is not like the others, interesting questions arise.

ONE MORE EXAMPLE

As a final example of a homogeneity chart I shall use the results of a complex skill test administered to 81 individuals. Each person had to repeat the test four separate times. The four test results for each person were then placed into a subgroup and these subgroups were used to create the average and range chart shown in Figure 5. The order of the subgroups on the chart is alphabetical by last name, and each individual is represented by their initials. (When using an arbitrary ordering such as this we cannot use run-test detection rules.)

The variation within each subgroup is the test-to-test variation for each individual. The variation between the subgroup averages represents the differences between individuals.

The range chart checks the within-subgroup variation for consistency. Here we see that, except for GC and SL, they all display about the same amount of test-to-test variation. GC and SL are found to have had slightly more test-to-test variation than the others.

Since the variation within the subgroups is the variation used to create the limits, the limits seen on the average chart represent the amount of uncertainty in the subgroup averages that can be attributed to the background test-to-test variation that virtually everyone displays. Thus, for the 79 subgroup averages that fall within the limits we have to say that the person-to-person differences are smaller than the within-person, test-to-test differences. In other words, it would be fair to conclude that these 79 individuals are all part of the same grand lot. They are all effectively demonstrating the same skill level. They are not detectably different from each other.

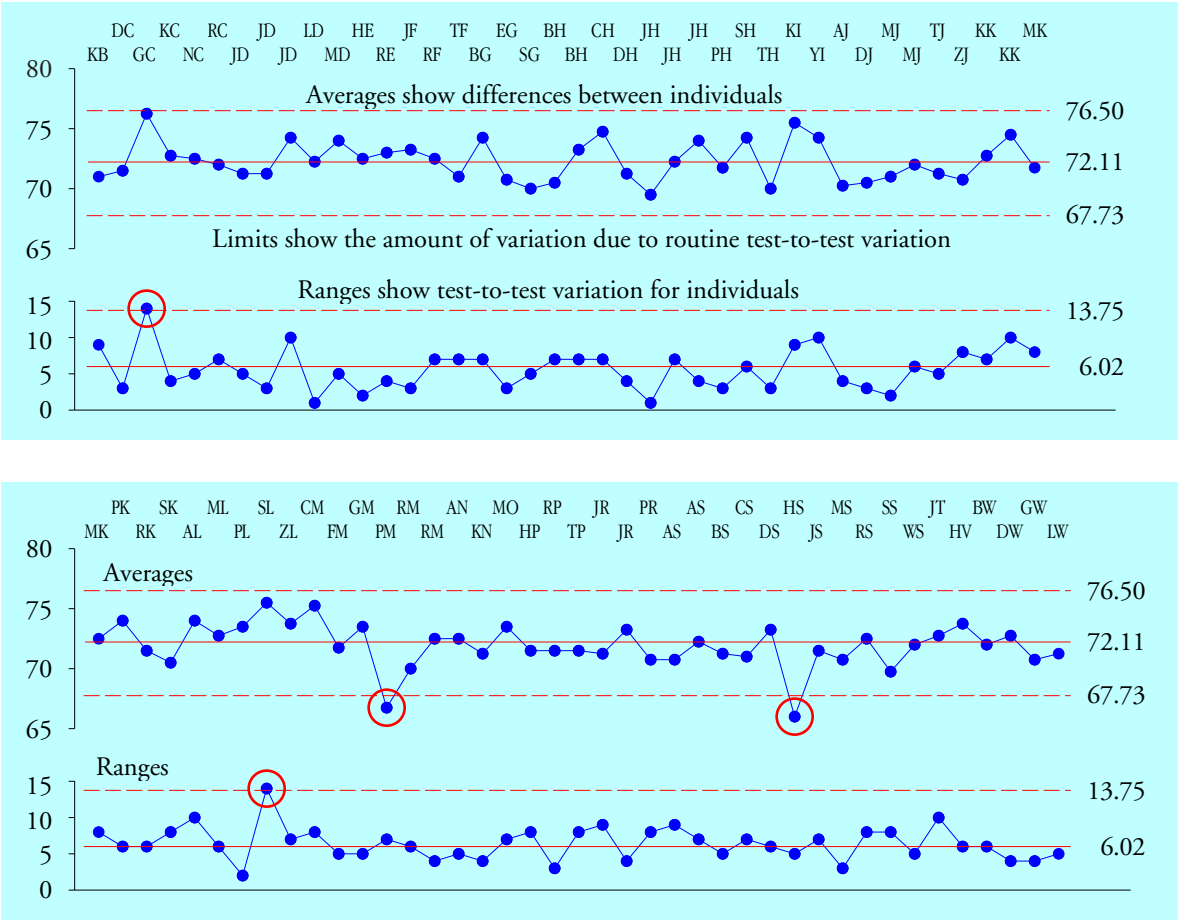

Figure 5: Homogeneity Chart for Skill Test Results for 81 Individuals

The two individuals with detectably lower test results, PM and HS, form a second grand lot. They were operating at a detectably different skill level than the other 79. These last two individuals are Henrik Stenson and Phil Mickelson at the 2016 British Open, and yes, they were playing golf at a detectably different level than everyone else that week.