Individuals Control Chart (XmR chart, I chart) Reporting

By Forrest W. Breyfogle III

Individuals control charts (*I*-charts or *X*-charts) can be used for time-series tracking of a process to determine if the process is in statistical control and can be considered stable. When a process is considered stable, it experiences only common-cause variability. When a process is not in control, special-cause conditions can be causing non-stability.

In a process, effort should be taken to understand and resolve, when appropriate, special-cause conditions. A process that only experiences common-cause conditions does not imply that the process does not have any issues. A process can be stable but be unable to provide a consistent level of quality or performance. Assessments for process stability and capability can be provided through 30,000-foot-level reports with predictive measurements.

A moving range chart can be included with an individuals control chart report-out, producing a pair of charts (i.e., *XmR* control chart or *ImR* control chart). However, since the primary purpose of the MR chart is only to identify larger than normal short-term swings in the data, this chart will not be included in the described report-outs so that the overall reporting and evaluation process can be simplified.

The data in Table 1 will be used to illustrate the mechanics of creating of an individuals control chart. We will consider that these data were collected using an infrequently subgrouping/sampling plan that is consistent with application of a 30,000-foot-level charting methodology.1 (For more information about 30,000-foot-level reporting and its benefits see Performance Metric Reporting Issues: 30,000-foot-level Resolution.)

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Time Sequence	Response	Moving Range (MR)
1	70.10	
2	75.20	5.10
3	74.40	0.80
4	72.07	2.33
5	74.70	2.63
6	73.80	0.90
7	72.77	1.03
8	78.17	5.40
9	70.77	7.40
10	74.30	3.53
11	72.90	1.40
12	72.50	0.40
13	74.60	2.10
14	75.43	0.83
15	75.30	0.13
16	78.17	2.87
17	76.00	2.17
18	73.50	2.50
19	74.27	0.77
20	75.05	0.78
Mean =	74.20	2.27

Modified from Table 10.2, *Integrated Enterprise Excellence Volume III - Improvement Project Execution: A Management and Black Belt Guide for Going Beyond Lean Six Sigma and the Balanced Scorecard*, Forrest W. Breyfogle III, Bridgeway Books/Citius Publishing, Austin, TX, 2008.

Table 1: Time-series Data

An individuals control chart has an upper control limit (UCL) and lower control limit (LCL), which are calculated from the raw time-series data. Charting parameters for the individual values chart are:

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$$\text{CL} = \bar{\bar{x}} \qquad \text{LCL} = \bar{\bar{x}} - \frac{3(\overline{\text{MR}})}{d_2} = \bar{\bar{x}} - 2.66(\overline{\text{MR}}) \qquad \text{UCL} = \bar{\bar{x}} + \frac{3(\overline{\text{MR}})}{d_2} = \bar{\bar{x}} + 2.66(\overline{\text{MR}})$$

The 2.66 factor is $3/d_2$, where 3 is for three standard deviations and d_2 is from Table J1 for a sample size of 2 (i.e., 3/1.128 = 2.66). This relationship can be used when the moving range is selected to expand beyond the adjacent samples. For this situation, the value for d_2 would be adjusted accordingly.

For the Table 1 data set, the MRs are determined from the relationship

$$\begin{aligned} \text{MR}_1 &= |x_2 - x_1| = |70.10 - 75.20| = 5.10 \\ \text{MR}_2 &= |x_3 - x_2| = |74.40 - 75.20| = 0.80, \ldots \end{aligned}$$

The process mean and moving range mean are calculated and used to determine the individual-measurement control chart parameters of

$$\begin{array}{lll} \text{CL} = \bar{\bar{x}} & \text{LCL} = \bar{\bar{x}} - 2.66(\overline{\text{MR}}) & \text{UCL} = \bar{\bar{x}} + 2.66(\overline{\text{MR}}) \\ \text{CL} = 74.200 & \text{LCL} = 74.200 - 2.66(2.267) & \text{UCL} = 74.200 + 2.66(2.267) \\ & \text{LCL} = 68.170 & \text{UCL} = 80.230 \end{array}$$

An individuals control chart of the Table 1 data with these calculated UCL and LCL is shown in Figure 1.

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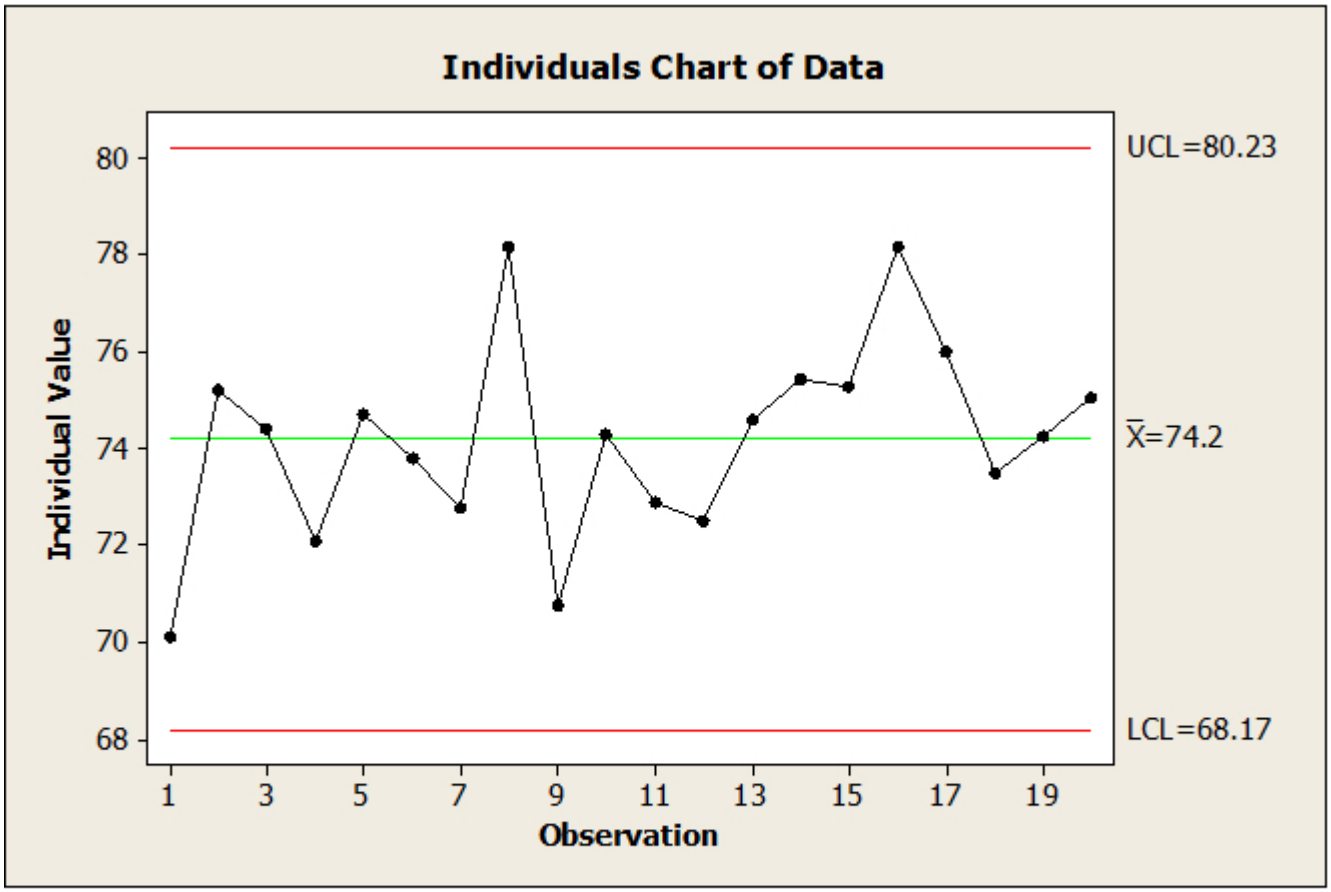

Modified from Figure 10.8, *Integrated Enterprise Excellence Volume III - Improvement Project Execution: A Management and Black Belt Guide for Going Beyond Lean Six Sigma and the Balanced Scorecard*, Forrest W. Breyfogle III, Bridgeway Books/Citius Publishing, Austin, TX, 2008.

Figure 1: Individuals Control Chart

From this figure the process is concluded to be in control and have a recent region of stability. This conclusion is made since there are no trends relative to or data points outside the statistically determined upper and lower control limits (UCL and LCL).

Since the process has a recent region of stability, one can conclude that the process is predictable. The up and down variability shown over time is from common-cause variability. Organizations should not react to individual common-cause values, which can lead to much firefighting; i.e., reacting to special-cause variability as though it were common-cause variability.

A probability plot can be useful to determine how a process that has a continuous response is performing relative to customer needs, where these desires are often conveyed through specification values. This data will

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be further analyzed for determining process capability (process performance) in the paper Probability Plotting: Quantifying Process Performance.

References

- Forrest W. Breyfogle III, *Integrated Enterprise Excellence Volume III - Improvement Project Execution: A Management and Black Belt Guide for Going Beyond Lean Six Sigma and the Balanced Scorecard*, Bridgeway Books/Citius Publishing, 2008

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About the Author
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In a professional career spanning over a quarter century, Forrest Breyfogle has established himself as a leading edge thinker, a prolific author, an innovative consultant, a world-class educator, and a successful business executive. His work is documented in eleven books and over ninety articles on the topic of quality improvement.

A professional engineer, Forrest is also a member of the board of advisors for the University of Texas Center for Performance Excellence. He is the founder and CEO of Smarter Solutions, Inc., an Austin, Texas based consulting firm offering business measurement and improvement consultation and education to a distinguished list of clients worldwide, including BAMA, CIGNA, Dell, HP, IBM, Oracle Packaging, Sherwin Williams, Cameron, TIMET, and TATA. He served his country on active duty in the US Army for 2 years, and has played an active leadership role in professional and educational organizations. Forrest received the prestigious Crosby Medal from the American Society for Quality (ASQ) in 2004 for his book, *Implementing Six Sigma* (second edition). This award is presented annually by the American Society for Quality to the individual who has authored a distinguished book contributing significantly to the extension of the philosophy and application of the principles, methods, or techniques of quality management. Mr. Breyfogle was named Quality Professional of the Year for 2011 by Quality Magazine and in 2012 was awarded alumni of the year by Missouri University of Science and Technology.

He is a widely recognized authority in the field of management improvement and is a frequent speaker before professional associations and businesses. His earlier work in the field of management science has been widely acclaimed. A previous book, *Implementing Six Sigma*, sold over 40,000 copies and still ranks among the top Amazon books in Applied Mathematics/Engineering Statistics and Industrial Engineering /Quality Control.

He founded Smarter Solutions in 1992 after a 24-year career at IBM. The associates of Smarter Solutions specialize in helping companies throughout the world improve their bottom line and customer satisfaction through the implementation of techniques that are beyond traditional Lean Six Sigma and the balanced scorecard methodologies. His latest and most extensive work has been in the documentation of a new system of enterprise management, the Integrated Enterprise Excellence (IEE) system, in a series of four books. IEE provides a detailed roadmap that builds on and integrates the best practices of earlier disciplines like Six Sigma, Lean, TQM , PDCA, DOE, and TPS combined with innovative analytical tools to produce improvements at the highest level of an enterprise.

In addition to assisting hundreds of major clients in the wise implementation of improvement systems worldwide, Forrest has also developed over 300 hours of classroom instruction used to train executives, managers, and Black Belt practitioners to plan for, implement, and manage IEE systems. He also leads formal seminars and workshops worldwide.

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