By Forrest W. Breyfogle III

C-charts are used in quality control to identify when special-cause or out-of-control conditions occur in time-series count data so that timely corrective actions can be taken to resolve problems. Sometimes data from a *c*-chart are also used to describe process capability.

However, there are issues in how *c*-charts are often created and applied. Related process-capability statements can have issues, too.

The application shortcoming of *c*-charts will be described in this article along with an alternative 30,000-foot-level charting methodology that not only addresses these issues but provides an enhancement to the techniques. The described methodology not only improves the accuracy of common-cause and special-cause statements but also provides a better and more easily understandable process-capability or process-performance statement that is predictive.

This article will build on the Shewhart[1] and Deming[2] special-cause and common-cause variability concepts described in Control Charting Issues: 30,000-foot-level Chart Resolution as it relates to *attribute count data that occur in subgroups.*

Traditional Control Charting

The examination of time-series data should lead to the most appropriate action or non-action to occur; however, a resulting conclusion of what action or non-action to take can be a function of how the data are examined. This point will be illustrated using the data in Table 1[3], which contains the number of incidents that occurs during a monthly subgrouping period.

Month	No.	Month	No.	Month	No.	Month	No.	Month	No.	Month	No.
1	0	11	0	21	0	31	0	41	1	51	0
2	0	12	1	22	1	32	0	42	1	52	0
3	1	13	0	23	0	33	1	43	0	53	1
4	1	14	0	24	0	34	0	44	1	54	0
5	0	15	0	25	1	35	1	45	0	55	0
6	0	16	1	26	0	36	0	46	1	56	1
7	0	17	0	27	1	37	0	47	0		
8	0	18	0	28	0	38	1	48	0		
9	1	19	0	29	0	39	0	49	0		
10	0	20	1	30	1	40	0	50	1		

From Table 13.2, *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: Number of Monthly Incidents

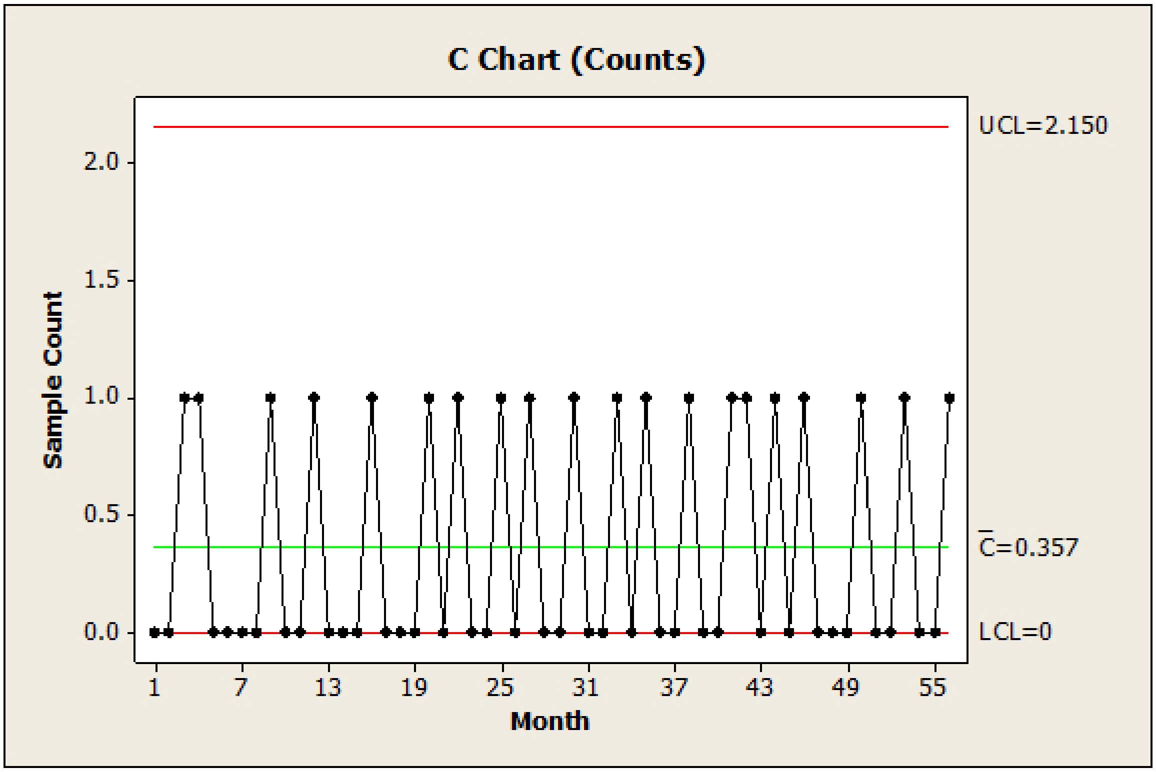
This data could be the number of safety or health incidents that occurs in an insurance company, hospital, or one-shift manufacturing facility during a period of time; i.e., month. In the following analyses, focus will be given initially to the assessment of process stability and then, if stable, a process-capability or process-performance statement could be made.

Traditionally count (*c*) occurrence data are tracked over time using a *c* chart to detect special cause occurrences. The lower control limit (LCL) and upper control limit (UCL) for this Shewhart[1] control charting strategy are determined using the relationships:

$$\text{LCL} = \bar{c} - 3\sqrt{\bar{c}} \qquad\qquad \text{UCL} = \bar{c} + 3\sqrt{\bar{c}}$$

From these equations, the LCL and UCL are determined using the average number of counts ($\bar{c}$) and subgroup size (n). Whenever a measurement is beyond the LCL or UCL on a control chart, the process is said to be out of control. Out-of-control conditions are special-cause conditions, which can trigger causal problem investigations. From these relationships, it can be noted that variability between subgroups has no impact on the upper or lower control limit calculations.

For the *c* chart of this data, which is shown in Figure 1, no causal investigations would have been initiated because there are no out-of-control signals. However, using this chart to make timely decisions can be very difficult because of the infrequent monthly subgrouping. Also, there are many zero values, which is desirable from a response point of view but not from a control charting perspective. One way to get around this problem for this set of data is to reduce the subgrouping frequency to, for example, quarterly, but that would make any decisions from using this chart even less timely.



From Figure 13.7, *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: c chart of monthly instances

30,000-foot-level Charting

An individuals (*X*) chart tracks an individual value over time where the chartôs control chart limits consider between-subgroup variability. When adjacent subgroups are used to determine average moving range ($\overline{MR}$), the *X* chart has a LCL and UCL of:

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

Unlike with a c-chart, the control limits for an individuals or *X* chart are a function of the average moving range between adjacent subgroups. The importance of capturing between-subgroup variability when calculating statistical process control chart upper and lower control limits was discussed in Control Chart Issues: 30,000-foot-level Chart Resolution

The *X* chart is not robust to non-normal data; therefore, for some situations, data need to be transformed when creating the control chart. One example of a non-normal condition is when there is or tends to be a natural boundary condition. For this situation, a control chart with no data transformation can cause false signals where common-cause variability appears as to be special cause.

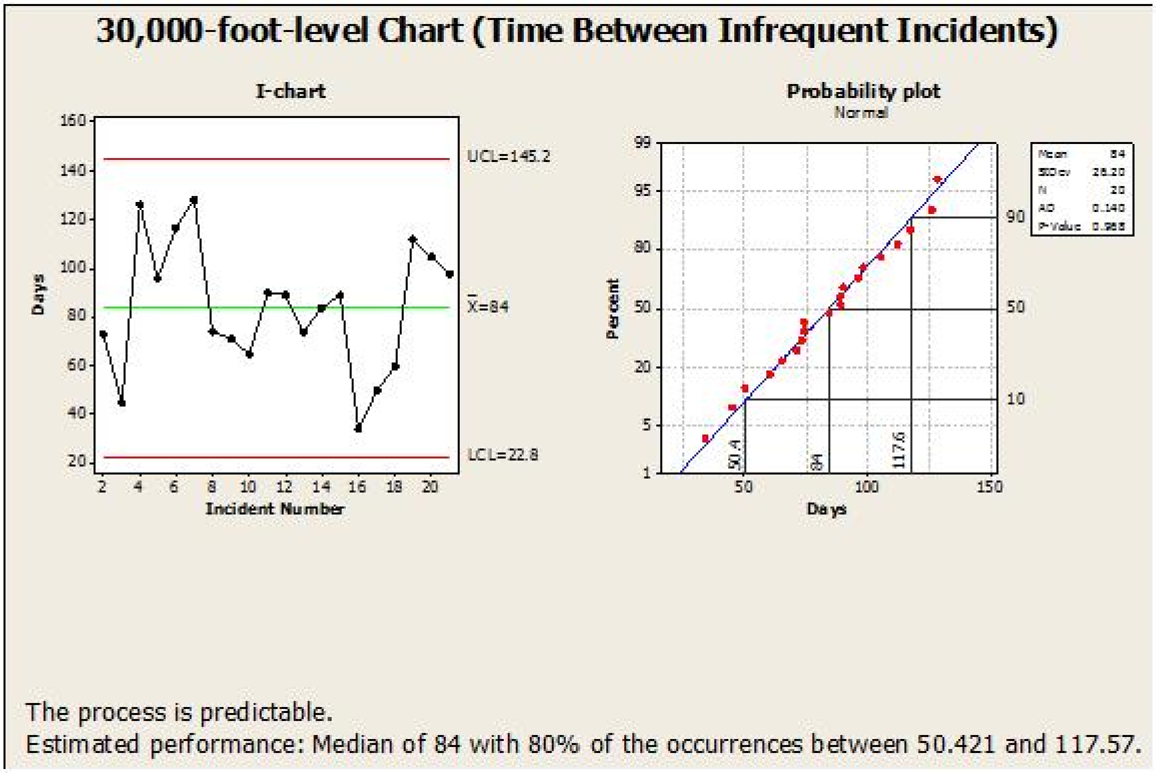
The process from which the Table 1 data originated has infrequent failures. Instead of the above format, consider now that the times between failures were recorded and presented in the format shown in Table 2. Note: this is not describing a different situation but an alternative approach for recording failure data.

Failure Number	Days since Last Failure	Failure Number	Days since Last Failure	Failure Number	Days since Last Failure
2	73	9	71	16	34
3	45	10	65	17	50
4	126	11	90	18	60
5	96	12	89	19	112
6	117	13	74	20	105
7	128	14	84	21	98
8	74	15	89		

From Table 13.3, *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 2: Time Between Each Incident

A 30,000-foot-level chart of this data is shown in Figure 2.



Modification of Figures 13.8 and 13.9: *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.

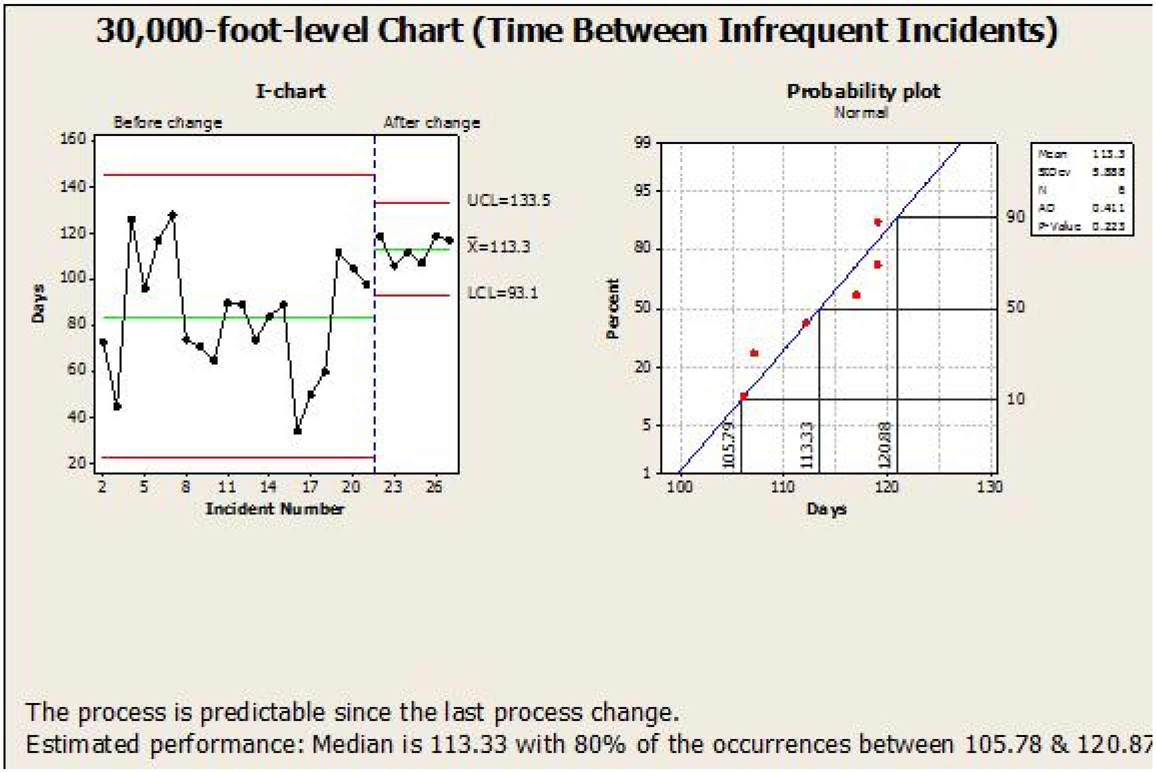
Figure 2: 30,000-foot-level Chart of Time between Incidents[4]

This chart indicates that our process is predictable with an estimated mean time between incidents or mean time between failure (MTBF) of 84 days. This value could be converted to an average annual or monthly incident rate.

Project Creation and Valuation

Consider that a cost analysis of these failures indicated that improvement was needed. This would be the 30,000-foot-level metric pulling (using a Lean term) for an improvement project creation.

Consider that a projectôs change was implemented, and this resulted in the 30,000-foot-level chart shown in Figure 4.



Modification from Figures 13.10 and 13.11, *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 4: 30,000-foot-level Chart Before and After Change[4]

This figure indicates that the process has reached a new stability/predictability level from its past level estimation of 84 hours between incidents. The new process capability/ performance metric estimate has a median of 113 (113.33 rounded off) and frequency of occurrence of 106 (105.78 rounded off) to 121 (120.87 rounded off). In time, when more data becomes available, this prediction estimate can be refined.

References

1. Walter A. Shewhart, *Economic Control of Quality of Manufactured Product*, ASQ Quality Press, 1931, reprinted in 1980.
2. W. Edwards Deming, *Out of the Crisis*, MIT Press, 1986.
3. 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
4. Figure created using Enterprise Performance Reporting System (EPRS) Software

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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