Discussion

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We thank the editor and author for the opportunity to comment on this timely and important topic. As Professor Woodall has done, we restrict ourselves to a discussion of control charting and leave other aspects of statistical process control for another time.

Attempting to be provocative, we pose the question

"Does control charting work?"

In our experience, the answer to the question is "not very well and not very often". Some support for this position is found in the final paragraph on control charts of Ishikawa's (1982) famous guide, where he wrote "Control charts are easy to construct so are widely used. But there are surprisingly few really useful charts". To be fair, the second sentence disappeared in later printings of the book.

Our goal here is to examine the above question and answer in light of the issues raised in Professor Woodall's paper.

To understand the question, we need to know what it means for control charting to work. There are several purposes for control charting. The classic use is to reduce variation in a output characteristic by establishing a control chart to signal the change of an unidentified process input. The occurrence of a signal sets off an effort to identify this input. If the search is successful, made more likely because of the recent change in the value of the input, then there is an attempt to remove or reduce the effect of this cause of variation. If this undertaking is also successful, then ongoing variation of the characteristic will be smaller. Further signals can lead to further reduction of variation by following the same procedure. If variation is reduced, control charting will have achieved its purpose. If signals are ignored, if corresponding inputs are not identified, or if their effects are not reduced, the process will continue as before and charting will have failed.

A second purpose for control charting is to determine when and by how much a process should be adjusted. A control chart is set up and adjustments are made only when a signal occurs. For variables charts, the recent history gives information about the size of the adjustment needed. Charting is successful if the process has smaller variability than previously. Here, there is a potential for a one-time only gain. In this application, control charting will not produce the ongoing variation reduction that may be achieved if the procedure associated with the first purpose is followed.

As an aside, in our view, it is within this application only that control charting and pre-control are comparable. Both are simple feedback controllers. When either of these adjustment schemes is put in place, the variation in the process may be reduced and targeting may be improved , depending on the previous control method and the nature of the process. The relative merits of pre-control and control charting can be assessed for any process by simulation, using a historical record of the process or experimentally, by trying each controller over a sufficiently long period. Given the advances in control theory (Box and Luceño (1997)) and the ability to make measurements on both process inputs and outputs, both methods perhaps belong in the "horse and buggy age".

A third purpose for control charting is to demonstrate that a process is stable. For example, a supplier may provide a customer with a control chart constructed over a production period to demonstrate the performance of the process. The customer can use the information provided by the chart to decide, for instance, that no receiving inspection is needed. Charting is successful if it provides useful information. In this context, there is no plan to look for causes of variation or to adjust the process based on the charting.

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Even here abuses are possible. We know of one example in the automotive sector where each shipment of pulleys from a supplier to a tier one assembly operation was duly accompanied by an X-bar and R chart for the inner diameter, a designated special characteristic. The chart showed that the process was stable. Both customer and supplier were happy with the system. The fact that the chart was identical each time, being a photocopy of the results from an early capability study did not seem to matter.

The point that we are trying to make is that we cannot address the question about whether or not control charting works unless we know the purpose. For the rest of our discussion, we suppose that the purpose is the classic one, to continually reduce variation by identifying and removing the effects of causes of variation. It is here, in our view, that charting has failed miserably, even though the potential benefits are the greatest. The question is why?

Professor Woodall points to one possible reason in his discussion of the role of theory. He notes that "researchers tend to neglect phase I applications and the vitally important practical considerations of quality characteristic selection, measurement and sampling issues, and rational subgrouping". Taking this point still further, it is helpful to think of charting as a system or "an overall SPC strategy" as Professor Woodall calls it in his conclusion. Elements of the system include those in the above quotation plus many more. For example, consideration should be given to the provision of resources and methodology to react when the selected chart signals. That is, when a signal occurs, who does what? In today's lean manufacturing environment, this is a critical issue since the signals are not predictable. Also, given the complexity of many processes, the cause of a signal can be far removed in both time and space from the chart location. With the limited resources available, it may be very difficult to trace changes in the inputs to the observed change of the monitored characteristic.

Research has concentrated on local optimization of this charting system. Theoretical models have been used successfully to derive ever more sensitive charts, to compare the properties of different charts under a wide variety of assumptions and to narrowly consider the economics of charting. It is past time for us to examine the system more broadly as Professor Woodall points out. For example, he suggests looking at variation transmission through the process. A useful starting reference is Lawless, Mackay, and Robinson (1999). Another suggestion is to consider plans to monitor simultaneously the characteristic of interest and a broad suite of process inputs. This would allow the analysis and detection of causes to move off-line. That is, the data can be examined at leisure, without the need to react instantly to a signal from a control chart. See Nomikos and MacGregor (1995). There are many challenging problems here, given the range of data types, the possible poor linkages between inputs and outputs, the inherent correlations among inputs, and so on.

Another, perhaps, less plausible reason for the failure of charting is its weak conceptual foundation. Consider, for instance, the basic definitions that we use, or perhaps abuse. Professor Woodall discusses some of these at the start of his section titled "Some Concepts of SPC". For instance, is a stable process the same as an in-control process the same as a predictable process? Is a special cause the same as an assignable cause? How can a common cause today become a special cause tomorrow, given that the only way to remove the effect of a common cause is to change the process itself? Even the word "control" in the name SPC causes endless confusion.

There is an implicit controversy about the answers to these questions. Review of the popular texts on SPC, for example Montgomery (1996) and Wheeler and Chambers (1992), will show that there is little agreement about the fundamental definitions of SPC. Do such disagreements matter in practice? Perhaps not greatly, but after explaining to a group of managers that it is critically important that they understand the difference between a common and special cause because each requires a different reaction, it is somewhat embarrassing not to be able to give a clear definition of which is which. "You'll know it when it you see it" seems a feeble answer and does not inspire a lot of enthusiasm or confidence.

It would be very helpful to develop (and, more importantly, to agree upon) a set of consistent, non-redundant definitions needed to describe control charting. Professor Woodall's introduction of Phase 1 and 2 seems helpful, although the definition of the transition from one phase to the next is still unclear. Presumably Phase 1 ends with the establishment of initial control limits. Each time control limits are recalculated (due to the improved performance of the process or a change in the sampling scheme), a new Phase 1 begins. Another notion that we find useful is that of a Process View, which includes the characteristics being monitored, the subgrouping scheme, the sampling frequency and the attributes being charted. The importance of this concept is that we believe that the basic definitions of SPC need to be view dependent, or what Professor Woodall calls "context dependent". For example, the stability of a process is view dependent. A manager looking at weekly scrap rates due to out of specification parts from a machining process may see a very stable process, whereas an operator within the process looking at a variable characteristic from 5 parts per hour may see chaos.

We do not believe that the controversy over whether or not control charting is a test of hypothesis has any connection to the success or failure of its application. It seems an entirely unimportant question which, whether you answer yes or no, has no effect on practice. Instead, we suspect that rancorous public debate over such arcane issues will not add to our credibility as researchers, nor encourage the effective use of the methodology we are proposing.

In summary, we propose that many of the controversies discussed by Professor Woodall can be made clearer if we start with an understanding of the particular purpose for which control charting is to be used. In the case where the goal is continual reduction of variability, we have given two reasons why control charting has not worked very well in practice. As a remedy to this poor performance, we suggest first that we need to look at the whole system of charting, not just the chart itself. Second, we need to strengthen the foundation of charting by clarifying, simplifying and reaching agreement on the fundamental definitions and assumptions.

We again thank the Editor for an opportunity to comment on this paper and congratulate Professor Woodall for his important contribution.

Additional References

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