Continuous Improvement with Control Charts

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ABSTRACT

The idea that great gains in productivity and quality can be made by continually improving a process is widely accepted. The basis for the improvement is a continuous accumulation and application of knowledge about how the process works. Control charts and the associated data collection procedures have traditionally been used for purposes such as process adjustment, process stabilization and record-keeping. This article examines the possibility of using control charts as the data collection method for continuous improvement. The functions which must be carried out are described and organized in a system. The conclusions of this examination are that great care must be taken in designing a system for continuous improvement around the chart and that for complex processes, it is very difficult to use a chart in this way.

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Introduction

It is now well recognized that great gains in quality and productivity can be made by working continuously on a day-to-day basis on a process. The improvements occur in many small increments and typically require small capital outlays but large amounts of effort from many individuals. The Japanese refer to the system of continuous improvement as "Kaizen".

In the context considered here, continuous improvement is equated with continuous reduction of variation about a target. For example, if the quality characteristic of interest is the hardness of a casting, the process is continuously improved if the variability of the hardness about the nominal value is made smaller and smaller. The reduction of variation leads to reduced scrap and rework, better machining properties, fewer problems with final surface finish and so on.

The foundation upon which continuous improvement is based is the idea that the more that is known about a process, the better it can made to operate. This means that to achieve continuous improvement, a system must be in place to capture data about the process, to convert this data into useful knowledge, and to implement changes in the process that reflect what has been learned.

Burr (1953) says that a control chart is " the process talking to us". This famous quotation suggests that a control chart is a very good way to collect data about a process for the purposes of gaining knowledge. The aims here are to examine critically this possibility and to describe aspects of the system that must surround the chart in order to achieve continuous improvement.

All comments in this paper refer to X-bar and R charts. The same points apply to other types of charts.

The Common Uses of Control Charts

There are many types of control charts and many uses for each type. The analogy to screw drivers is a good one. The list of uses for charts which follows reflects my own experience. I am certain the list is incomplete. The order in the list corresponds to the relative order of usage that I have observed.

1. A control chart is used to help the operator to decide if a process adjustment is necessary. The adjustment involves, for example, re-tooling, resetting controls, or routine maintenance.
2. A control chart is used as a record of process performance. A customer of the process may demand a chart as a substitute for inspection.

3. A control chart is used as a tool to analyze data collected for a special study. For example, in a multi-palette process, periodic studies are done to determine which palettes, if any, are performing differently from the rest. The study involves collecting a subgroup of data from parts produced on each palette and comparing the subgroup averages and ranges using an X-bar and R chart. Palettes which correspond to out-of-control points on the chart are subject to special maintenance.
4. A control chart is used to help to establish process stability. Note that a stable process is one that is in statistical control, so that in some sense, process performance is predictable. This is the classical use of control charts but one that is infrequently applied. See for example discussions by Grant and Leavenworth (1988), Wheeler and Chambers (1986), and the ATT Handbook (1985).

It is difficult to connect any of the above uses of a control chart with the idea of continuous improvement. For example, once an adjustment program is in place or a process is stablized, the goal of using the chart has been met and further process improvement will not take place through the use of the chart.

To use a control chart for continuous improvement, we need to re-examine the underlying basis for the chart. This is done in the next section.

Control Charts and Process Stability- The Classical Approach

The underlying basis for using a control chart is the concept of a stable process. A process is stable if its output is predictable. This does not mean that the output is constant. Rather, it is the pattern of variation of the output that is constant. A histogram of a large sample of measurements taken from a stable process will always be the same. If a process is stable, the behaviour of the average and range of a small subgroup of observations is also predictable. This prediction determines the control limits on the chart. Any average or range outside the control limits is outside the normal range of behaviour and hence is a signal that the process has become unstable. That is, something has changed.

The change in the process which produces a signal of instability is often called a special or assignable cause of variation. When the special cause acts, it produces a change in the process that is large enough to be noticed against the background variation that is always present. The background variation is due to what are called common or chance causes. A common cause, when acting, produces a small change in the process which is not noticeable because of all the other variability present.

It is usually assumed that in any process there are many common causes and few special causes of variation. To achieve stability, the idea is to determine the special causes, and then to prevent them from acting. At this point, only common causes will act on the process, each with a small effect, and so the process will be stable.

Although easily stated, this is a difficult task to undertake. The chart is usually easy to set up. However, in complex multi-stage processes, once the chart signals the action of a special cause, it may be hard to find the cause. Also, the action of the cause is often outside the jurisdiction of the operator or individual charged with responsibility for keeping the chart. Furthermore, since the chart may signal at any time, it is difficult to organize people's schedule to look for the cause. If the action of the cause is relatively short-lived, then lack of immediate response will make isolation of the cause impossible.

Once a special cause is located, it is frequently not easy to prevent the cause from acting again. For example, if batch to batch variation in a raw material is an assignable cause, informing the supplier will have little effect. Instead, the supplier will have to find a way to reduce variation in the raw material (a new study in itself) or the process will have to be operated in a different way in which the effect of raw material variation is reduced. This second approach is one of Taguchi's (1979) basic methods for reducing variation, and requires a further study of the process.

Control charts are often established to help achieve process stability without sufficient consideration of the difficulties mentioned above. Even if these problems are overcome, once the process is made stable no further improvements will occur and the chart may as well be abandoned (except as a record of process performance).

Control Charts for Continuous Improvement

To use a control chart for continuous improvement requires that we abandon the idea of special and common causes of variation. Instead, it is useful to think simply of causes of variation. The charting procedure will be designed to find the causes responsible for large variations first. Once these causes have been removed, the procedure can be altered to find the largest of the remaining causes. This change in charting procedure and cause removal continues as long as is justified by economic considerations. The assumption for the approach is that there is a Pareto-like effect among the various causes. That is, there are a large number of causes, only a few of which have a relatively large effect. Once these have been removed, another few causes emerge as major contributors to the overall variation. In other words, some of today's common causes become tomorrow's special causes once today's special causes are remedied.

The approach described above demands a system for proper use. It will not work, for example, to teach operators of a machine how to construct a control chart and then turn them loose and expect to see continuous improvement. Experience has shown that this leads to frustration, anger and the eventual abandonment of the chart because so many of the causes are outside the operator's area of control. It is not the chart that is at fault but the lack of a proper system. Below, a possible system for continuous improvement which uses control charts is described.

A System for Continuous Improvement Using Control Charts

The system has several major components.

1. A management team to decide which processes to attack, to establish teams to work on the project, to allocate resources and to review progress. The team will also be involved in decisions to remove a cause of variation by a solution which

requires a capital outlay or a major change in operating procedure.

2. A team to set up and monitor the study. This group should include at some time representatives of everyone with an interest in the process including operators, engineers, maintenance, suppliers, customers etc. The basic task of the team is to isolate the causes of variation.

3. A team to find ways to remove or remedy causes of variation. This team will include members from the first two teams and must have authority to make changes in the process and to institute new studies on the processes for which the isolated cause is an output. For example, if an operating temperature is isolated as an important cause of variation in the characteristic of interest, it may be necessary to study the process which controls the temperature in order to reduce temperature variation and hence remove the cause of variation of the characteristic of interest. The team requires special skills in investigating non-capital intensive solutions for removing causes of variation.

4. An individual or small team who simultaneously collect the data on the characteristic of interest and on the status of the high priority causes. This group is a subset of the team described in 2 and will receive strict instructions from that team on when ,how and what data to collect. This team should also summarize the data collected in a convenient form for the cause-hunting team.

The role of each team is clear and it seems unlikely that the project can be successful without each of these roles being filled. If a simple process is being studied, such an elaborate system is probably unnecessary. However, all of the functions are required. The tasks of the second team are described in more detail in the next section.

The Cause Hunting Team

This team must have a systematic approach to its task. The suggestions given below correspond directly to the steps in any problem solving system. Here they are adapted to apply to a study in which a control chart is the basic tool for collecting and analyzing the data and the purpose of the study is to reduce continuously process variability.

1. Define the process as it is. The description must reflect reality, not intent. A thorough review of what is known about the process including information from suppliers and customers, data and conclusions from previous studies etc. should be part of this step.

2. Specify the characteristics of the process on which the improvement effort will be concentrated. This step must be done very carefully to avoid the waste of resources. The customers (i.e. those who are affected by the output of the process) must be consulted at this stage.

3. Identify the potential causes of variation in the important characteristics. Note the emphasis on the word "potential". At this stage, all possibilities must be considered. The goal is not to identify actual causes. Input from a large variety of sources should be solicited.
4. Prioritize the potential causes on the basis of their perceived importance, the ease of removal, and the ability to measure or track the associated factor. For example, if source of raw material is a potential cause of variation but it is impossible to identify the source upon production, this cause should be ignored. This does not eliminate the cause but since the charting effort cannot identify it there is no point in considering this potential cause until a tracking procedure is installed.
5. Select the top few high priority potential causes. The number considered depends on the resources available to the group who are responsible for reacting to the signals from the chart.
6. Evaluate the measurement systems for all important characteristics and factors associated with the selected causes. Make certain that, whenever a characteristic is measured, it is possible to identify the state of the potential causes.
7. Define the sampling scheme for the control chart. The step includes specification of the rational subgroup including size and frequency of collection. The rational subgroup must be defined so that if one of the high priority potential causes is acting (and the cause is actually important), the statistical properties of the measurements in the subgroup should be changed. For example, suppose a multi-spindle machine is part of the process and one of the high priority potential causes effects individual spindles and not the whole machine (eg tool properties). Then the subgroup should be made up of measurements on parts produced from one spindle only. Different subgroups can be taken from different spindles. Since there are several potential causes of interest, great care must be taken to define the subgroup so that the possible effects can be detected.
8. Set up the charting procedure including the assignment of responsibility for collecting and recording the data (both on the characteristics and the potential causes), summarizing the data, identifying signals from the chart and documenting the efforts. This step must be carefully managed because if the procedure breaks down no progress can be made.
9. Establish a regular review of what has been learned about which of the potential causes are important and which are not. Document the evidence for the team responsible for removing the important causes. Change the priorities on the potential causes as more is learned and adjust the charting procedure as described in step 7. Analyze the data collected in the longer term to monitor the improvement being achieved and the cost of the effort.

Conclusions

The procedure described above is complicated and requires dedication, discipline, and careful management. It has no fixed time horizon and is hence difficult to budget. For these reasons, it should not be undertaken lightly. With large complex processes it is not practical. Other quality improvement methodologies such as designed experiments are more appropriate in those cases.

The system is an example of an observational study. There is no manipulation of the causal system to see the effects. This is an advantage if the process under study is in production as the study method does not in any way interfere with the process. However, the study will have great difficulty unravelling the effects of causes which interact. Also, the causal factors under consideration will never move outside their normal operating range in this type of study. Again, only a controlled study such as a designed experiment can solve these problems.

The purpose of describing the system in such detail is to emphasize how many aspects must be taken under consideration when using control charts for continuous improvement. It is often stated that continuous improvement can be achieved with little capital expenditure but with a great deal of tenacity and effort. This certainly applies if a control chart is the statistical tool of preference.

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