CONTROL CHARTS

Category: Monitoring - Control

ABSTRACT

Control charts[(G)] are line graphs in which data are plotted over time, with the addition of two horizontal lines, called control limits, the upper control limit (UCL) and the lower control limit (LCL). The vertical axis represents a measurement and the horizontal axis is the time scale.

KEYWORDS

Control chart, run chart, upper control limit, lower control limit, Statistical process control

OBJECTIVES

To monitor – control a process over time.

FIELD OF APPLICATION

GENERAL APPLICATION

Control Charts can be used[2]:

- When controlling ongoing processes by finding and correcting problems as they occur.
- When predicting the expected range of outcomes from a process.
- When determining whether a process is stable (in statistical control).
- When analyzing patterns of process variation from special causes (non-routine events) or common causes (built into the process).
- When determining whether your quality improvement project should aim to prevent specific problems or to make fundamental changes to the process.

IN HEALTHCARE.

It can be used for general monitoring and improvement of hospital performance, monitoring of health-related variables for individual patients, surveillance of infectious diseases etc.

RELATED TOOLS

Six Sigma, Statistical Process Control (SPC)

DESCRIPTION

Control charts has been introduced by Walter A. Shewhart of Bell Telephone Laboratories in 1924[1].

WHAT IS A CONTROL CHART

The control chart is a graph used to study how a process changes over time. Data are plotted in time order. A control chart always has a central line for the average, an upper line for the upper control limit (UCL) and a lower line for the lower control limit (LCL). These lines are determined from historical data. By comparing current data to these lines, you can draw conclusions about whether the process variation is consistent (in control) or is unpredictable (out of control, affected by special causes of variation).

Control charts for variable data are used in pairs. The top chart monitors the average, or the centering of the distribution of data from the process. The bottom chart monitors the range, or the width of the distribution. If data were shots in target practice, the average is where the shots are clustering, and the range is how tightly they are clustered. Control charts for attribute data are used singly[2].

CONTROL CHART BASIC PROCEDURE[2]

1. Choose the appropriate control chart for your data.

2. Determine the appropriate time period for collecting and plotting data.

3. Collect data, construct your chart and analyze the data. To construct the control chart the following process should be followed[4]:

   ✓ Compute the sample mean and range as follows:

   $$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}, \qquad R = x_{max} - x_{min}$$

   ✓ If you feel that the process is stable, select *k* successive samples and compute the following values:

   $$\bar{\bar{x}} = \frac{\sum_{i=1}^{k} \bar{x}_i}{k} \qquad \bar{R} = \frac{\sum_{i=1}^{k} R_i}{k}$$

   You usually choose a value of *k* between 20 and 30. The value of $\bar{\bar{x}}$, which is an estimate of $\mu_{\bar{x}} = \mu$, becomes the center horizontal line on the $\bar{x}$ chart, and $\bar{R}$ becomes the center horizontal line on the R chart.

   ✓ Compute lower and upper control limits for $\bar{x}$ as follows:

   $$LCL_{\bar{x}} = \bar{\bar{x}} - A_2\bar{R}, \quad UCL_{\bar{x}} = \bar{\bar{x}} + A_2\bar{R}$$

Constant A_2 is depend upon sample size and can be found in statistical tables

4. Look for "out-of-control signals" on the control chart. When one is identified, mark it on the chart and investigate the cause. Document how you investigated, what you learned, the cause and how it was corrected.

5. Continue to plot data as they are generated. As each new data point is plotted, check for new out-of-control signals.

6. When you start a new control chart, the process may be out of control. If so, the control limits calculated from the first 20 points are conditional limits. When you have at least 20 sequential points from a period when the process is operating in control, recalculate control limits.

OUT-OF-CONTROL SIGNALS

- A single point outside the control limits. In Figure 1, point 16 is above the UCL (upper control limit).

- Two out of three successive points are on the same side of the centerline and farther than 2 σ from it. In Figure 1, point 4 sends that signal.

- Four out of five successive points are on the same side of the centerline and farther than 1 σ from it. In Figure 1, point 11 sends that signal.

- A run of eight in a row are on the same side of the centerline. Or 10 out of 11, 12 out of 14 or 16 out of 20. In Figure 1, point 21 is eighth in a row above the centerline.

- Obvious consistent or persistent patterns that suggest something unusual about your data and your process.

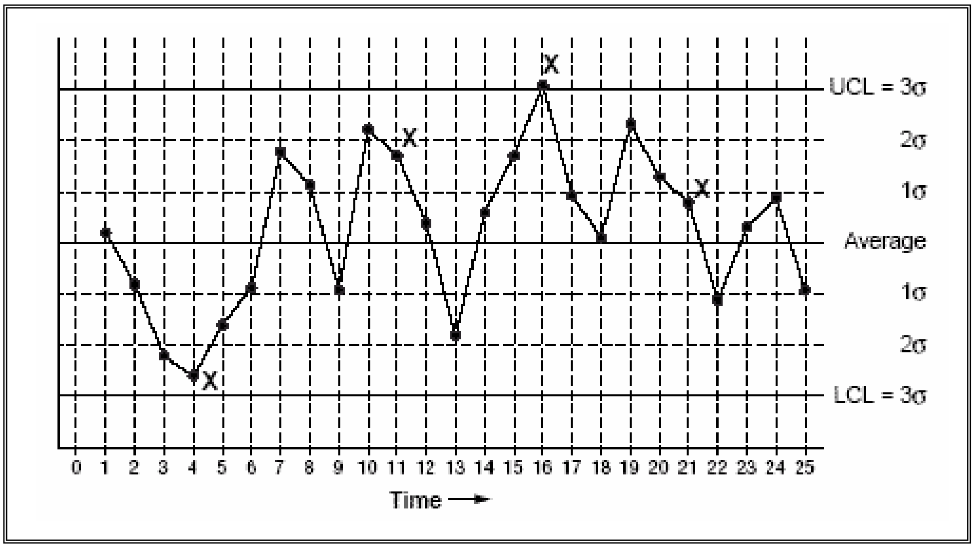


Figure 1: Sample Control Chart

TYPES OF CONTROL CHARTS

There are two main categories of Control Charts, those that display attribute data, and those that display variables data.

Attribute Data: This category of Control Chart displays data that result from counting the number of occurrences or items in a single category of similar items or occurrences. These "count" data may be expressed as pass/fail, yes/no, or presence/absence of a defect.

Variables Data: This category of Control Chart displays values resulting from the measurement of a continuous variable. Examples of variables data are elapsed time, temperature, weight and radiation dose.

The charts most commonly used for variables data are the $\bar{x}$-chart and the R-chart (range chart). The $\bar{x}$-chart is used to monitor the centering of the process, and the R-chart is used to monitor the variation in the process[5].

Finally, several alternatives to the popular $\bar{x}$ and R-charts are available and can be used in special cases.

As shown in Table 1, the chart type to use in any particular situation is based on identifying which type of data is most appropriateAs shown in Table 1, the chart type to use

in any particular situation is based on identifying which type of data is most appropriate[6].

Type of Control Chart	**Probability Distribution**	**When Appropriate to Use**	**Examples**
Xbar and *S* (Plot sample mean and standard deviation)	Normal (Gaussian)	Continuous measurements with "bell shape" Note: *Xbar* and *R* sometimes used as an alternative, al- though statistical properties are not as good. ('Individuals' chart should be used only as a last resort for same reason.)	Length of patient waits Procedure durations Timing of perioperative antibiotics Physiologic data Time from decision to first incision for emergent Cesarean deliveries
np (Plot sample total)	binomial	Total number of dichotomous cases generated by a process that result in a certain outcome Note: Sample size assumed constant for each sample	Number of surgeries that develop a surgical site infection Number of patients who receive an antibiotic on time Number of patients readmitted
p (Plot sample fraction)	binomial	Fraction of dichotomous cases generated by a process that result in a certain outcome Note: Sample size can change from sample to sample	Fraction of surgeries that develop a surgical site infection Fraction of patients who receive an antibiotic on time Fraction of patients readmitted
c (Plot sample rate)	Poisson	Total number of some event, where no exact upper bound, can be more than one event per patient or sampling unit Note: Assumes constant op-portunity or sampling area in each time period	Number of patient falls Number of central line infections Number of ventilator associated pneumonias Number of needle sticks
u (Plot sample rate adjusted per common base)	Poisson	Rate of some event, where no exact upper bound, can be more than one event per pa-tient or sampling unit Note: Rate is adjusted to av-erage per some common sam-pling denominator size	Average number of patient falls per 100 patient days Number of central line infections per 100 line-days Number of ventilator associated pneumonias per 100 ventilator days
g (Plot count between events)	geometric	Number of cases or amount of time between occurrences. Note: Particularly useful for rare events or when rate is low (e.g., rate < .01)	Number of surgeries between infec-tions Number patients between compli-cations Number days between adverse drug events Number days between needle sticks

Another way to choose the appropriate control chart is presented in Figure 2.

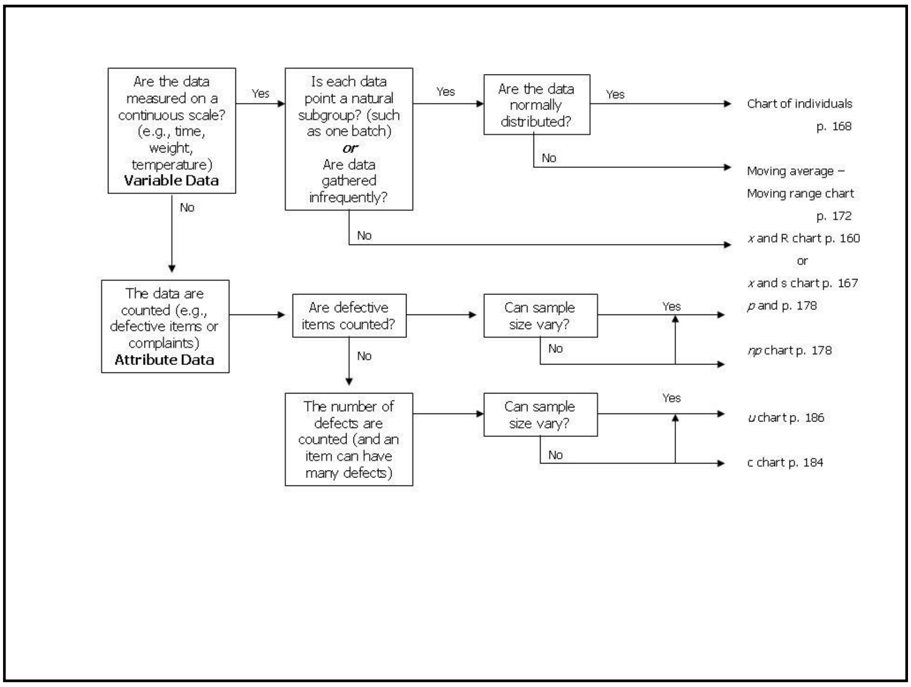


Figure 2: Control chart selection decision tree

BENEFITS

- Easy monitoring of evolution of data over time.
- Support alert system informing about undesirable results.
- Distinguishes special causes from common causes of variation.

PREREQUISITES

- Knowledge of statistics and availability of data.
- Data monitoring systems

EXAMPLES – CASE STUDY

IMPACT OF CHANGE OF MEDICATION ON BLOOD PRESSURE[3]

When the writer's annual physical disclosed that his heart had a leaky valve as well as high triglycerides, the blood pressure became of concern. Initially a generic drug was tried without a great deal of effect. Then the doctor switched to a new brand name drug. The question of whether that switch was effective in the writer's case is shown dramatically in figure 3.

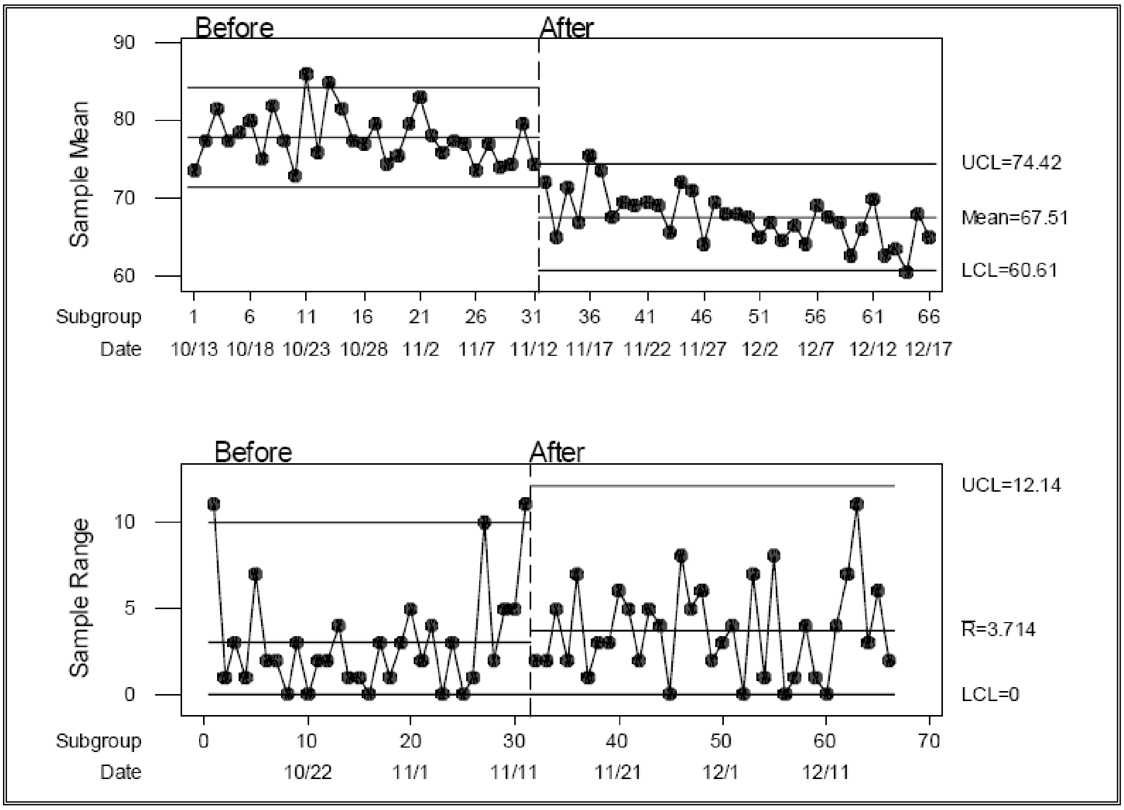


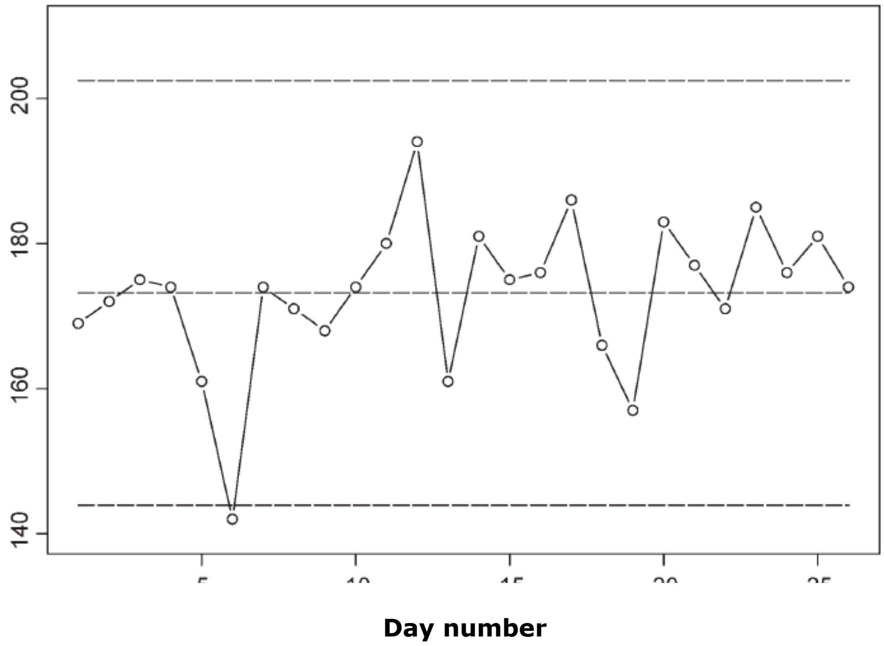
Figure 3: Impact on Blood Pressure

Figure 3 shows an X, R-chart and, as can be seen, the switch showed a dramatic decline in blood pressure. The generic drug is shown by the "before" section, while the impact of the brand name drug is clear in the "after" section of the chart. The change resulted in a special cause for the better. Health care providers tend to measure outcomes on a few observations. It may pay them to use the control chart as a means of determining the efficacy of their prescriptions.

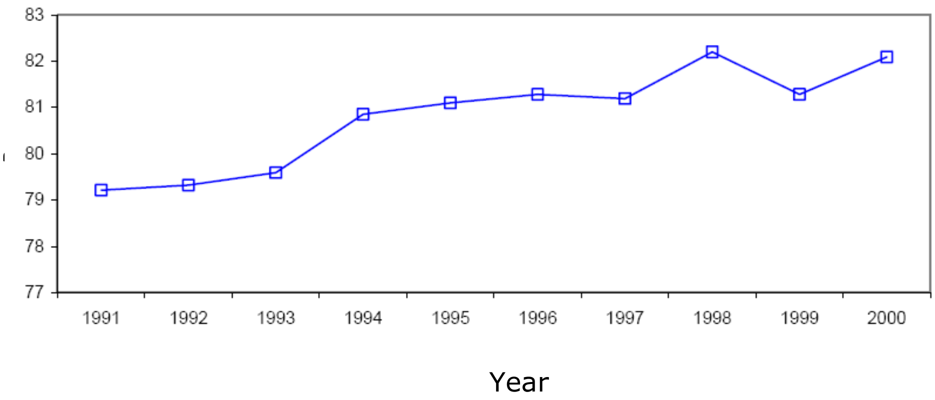
OTHER EXAMPLES OF CONTROL CHART USE.

In the following figures various examples of control charts use in healthcare applications are shown.

EXAMPLE 1: MONITOR OF DAILY SYSTOLIC BLOOD PRESSURE (MMHG) READINGS FOR A HYPERTENSIVE PATIENT[7].



EXAMPLE 2: SCOTTISH SURVIVAL RATE FOR 30 DAYS AFTER EMERGENCY ADMISSION FOR ACUTE MYOCARDIAL INFARCTION.



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