

Guide to quality control and performance improvement using qualitative (attribute) data —

**Part 1: Uses and value of attribute
charts in business, industry, commerce
and public service**

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Foreword

BS 5701-1 demonstrates the business benefits, and the versatility and usefulness of a very simple, yet powerful, pictorial control chart method for monitoring and interpreting qualitative data. This is done in a practical and largely non-statistical manner. BS 5701-1:2003 partially supersedes BS 5701:1980 and BS 2564:1955 and all four parts of BS 5701 together supersede BS 5701:1980 and BS 2564:1955, which are withdrawn.

This qualitative data can range from overall business figures such as percentage profit to detailed operational data, such as percentage absenteeism, individual process parameters and product/service features. The data can either be expressed sequentially in yes/no, good/bad, present/absent, success/failure format, or as summary measures (e.g. counts of events and proportions). For measured data control charting, refer to BS 5702-1.

The focus is on the application of control charts to monitoring, control and improvement. The roles of associated diagnostic, presentation and performance improvement tools, such as priority (Pareto) analysis, cause and effect diagrams and flow charts are also shown.

Its aim is to be readily comprehensible to the very extensive range of prospective users and so facilitate widespread communication, and understanding, of the method. As such, it focuses on a practical non-statistical treatment of the charting of qualitative data, presenting examples of construction and application using a simple pictorial approach.

Whilst the treatment of charting of qualitative data in this part of BS 5701 is essentially at appreciation level, it is intended to provide adequate information for a gainful first application, by a typical less statistically inclined user, in many everyday situations. BS 5701-2 and BS 5701-3 provide a more rigorous, statistical approach to process control and improvement using qualitative data. BS 5701-4 deals with measuring and improving the quality of decision making in the classification process itself.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 27 and a back cover.

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1 Scope

BS 5701-1 describes, in lay terms, the uses and value of pictorial control chart methods for enhancing the presentation and general understanding of qualitative (attribute) data arranged in a meaningful sequence. It also illustrates the supporting roles of associated business improvement tools. These include process modelling, flow charting, prioritizing (Pareto analysis) and cause and effect diagrams.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN ISO 9000:2000, *Quality management systems — Fundamentals and vocabulary*.

BS ISO 3534-1, *Statistics — Vocabulary and symbols — Part 1: Probability and general statistical terms*.

BS ISO 3534-2, *Statistics — Vocabulary and symbols — Part 2: Applied statistics*.

3 Terms, definitions and symbols

For the purposes of this part of BS 5701, the terms, definitions and symbols given in BS ISO 3534-1, BS ISO 3534-2 and BS EN ISO 9000:2000, Clause 3 apply.

4 Qualitative (attribute) data fundamentals

4.1 General

In this technological age, we are awash with data. The challenge is to transform such data into meaningful information on a characteristic. There is a wide range of classes of characteristic, including:

- a) physical (e.g. mechanical, electrical, chemical or biological);
- b) sensory (e.g. relating to smell, touch, taste, sight or hearing);
- c) behavioural (e.g. courtesy, honesty or veracity);
- d) temporal (e.g. punctuality, reliability or availability);
- e) ergonomic (e.g. linguistic, physiological or relating to safety);
- f) functional (e.g. range, speed, or rate of climb of an aircraft).

Typical business application characteristics, shown in Table 1, that are the subject of control and progressive improvement further indicate the wide scope of the subject matter of this standard.

Table 1 — Typical business applicable characteristics

Business application	Characteristic
business	profitability
marketing	market share
staff	absenteeism
personnel	turnover
sales enquiries	results
organization overall	errors/faults
product	non-conformities
service	complaints
incoming phone calls	response delays
invoicing	accuracy
deliveries	lateness
accounts	overdue
vehicles, machines	status
warranty costs	over-run
software	errors/10 ³ lines
computers	status
communications	clarity, timeliness

4.2 Types of data

Two general classes of data are distinguished here, *measured data* and *attribute data*. These classes can be otherwise termed *continuous data* and *discrete data* or, even, *quantitative data* as opposed to *qualitative data*. Whereas continuous data is measured on a numerical scale with a continuum of possible values, discrete data is referenced on a scale with only a set or sequence of distinct values.

This standard focuses on attribute data. Attribute data are divided for convenience, into two categories, *classified data* and *count data*.

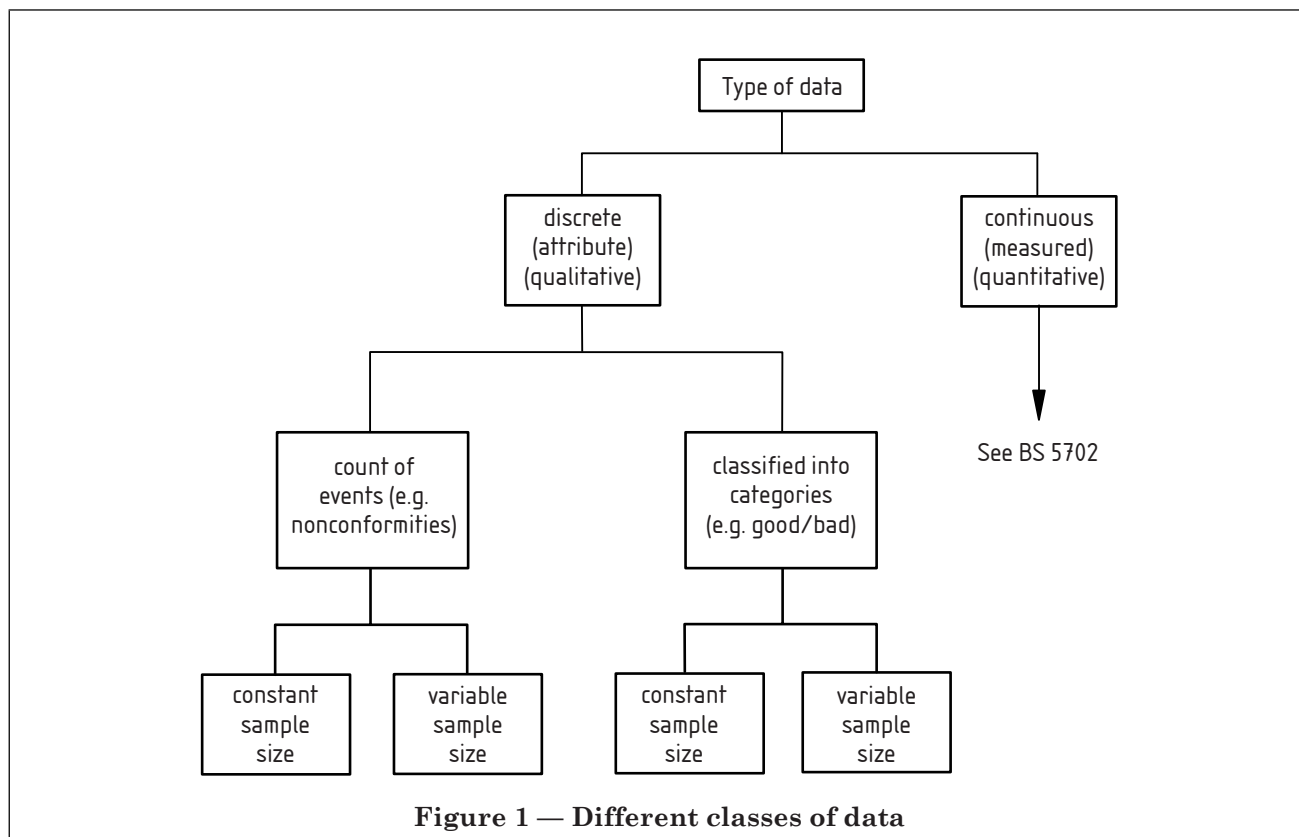
With *classified data*, each item of data is classified as being one of a number of categories. Frequently the number of categories is two, namely a binary situation where, for instance, results are usually expressed as 0 and 1, or as, good/bad, success/failure, profit/loss, in/out, or presence/absence of a particular characteristic or feature.

Data having two classes are termed “binomial” (binomial = “two names”) data. A measure can be inherently binomial, e.g. where a profit or loss is made, or if someone is in or out. Sometimes it is arrived at indirectly by categorizing some other numerical measure. Take, for instance, the case where telephone calls are classified as to whether or not they last more than ten minutes or, perhaps whether or not they are answered within six rings.

Count data relates to counts of events where each item of data is the count of the number of particular events per given time period or quantity of product. Instances are:

- number of accidents or absentees per month;
- number of operations or sorties per day;
- number of incoming telephone calls per minute; or
- number of non-conformities per unit or batch.

A pictorial representation of the different types of data is shown in Figure 1.



4.3 Principles, objectives and rationale of the control charting of qualitative data

4.3.1 Overview

Mention of the word statistics invokes a feeling of apprehension in many people. However, everyone should positively respond to, understand and adopt the primary concepts of “statistical thinking”. These are as follows:

- 1) All work occurs in a system of interconnected processes.
- 2) Variation exists in all processes.
- 3) Elimination of special cause variation produces process stability and predictability.
- 4) Reduction in common cause variation is the key to continual improvement.

The first concept highlights that “statistical thinking” should not be confined to a specific function of an organization. It is applicable across the whole spectrum of business activity.

The second concept brings out that variation is present in almost everything. Its existence provides opportunities for better process control and for process performance improvement.

The third and fourth concepts stress the need to clearly distinguish between the variation due to “special causes” and that due to “common causes”. The reason for this is that they give rise to two quite different types of action. A special cause is a sporadic source of variation that demands specific action to restore the status quo. A common cause, on the other hand, is an endemic source of variation that is always present, as it is inherent to the process. A reduction demands fundamental changes to the process.

The elimination of special causes brings a process back under control. The process performance or capability is then stable and predictable. A stable process might, or might not, provide the desired performance. A reduction in common cause variation improves process capability or performance.

A control chart is the tool used to differentiate between “special causes” and “common causes”. Hence the control chart is a key operational tool in the application of “statistical thinking”.

By its very name, a primary role of a control chart, in an operational sense, is to control; namely to inhibit change. The removal of adverse special cause variation to bring a process back into control does not actually improve the process: it only returns it to its original state.

It should be borne in mind, too, that a special cause can be adverse or beneficial. Suppose a supervisor stands in momentarily for an operator in a process and a special cause is indicated on a fault chart. The special cause could be a single reading above the upper control limit indicating an adverse change. Alternatively, it could be a single reading below the lower control limit indicating a beneficial change. The reaction to the two types of special causes would be quite different.

This focus on control, however, should not blind one to the fact that often the objective, in an overall sense, is to improve process performance by inducing change. Such betterment, through common cause reduction does not necessarily have to await special cause removal. However, the prior removal of special causes gives rise to a stable process and so permits a quantitative prediction of process capability. The generic control and improvement sequence is shown in Figure 2.

A significant improvement in process performance is evidenced in a control chart by an “out of control” situation, as is a significant deterioration. Hence the control chart has an in-built statistical test of significance for both improvement and deterioration.

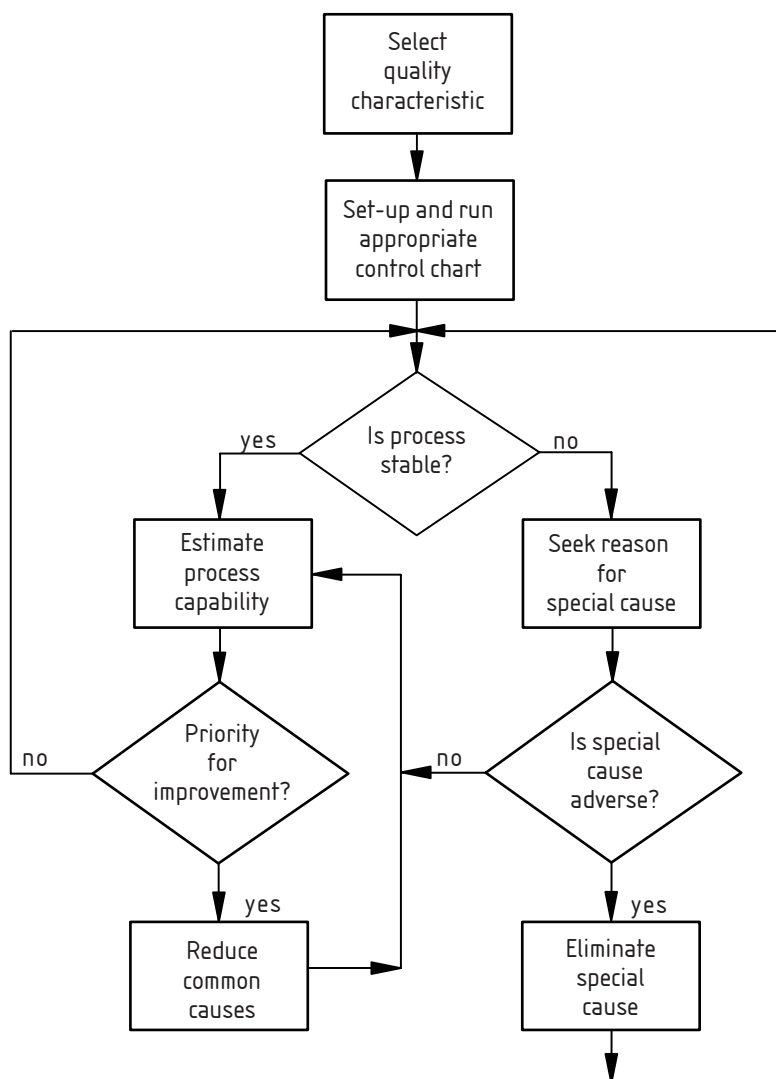


Figure 2 — Process control, capability estimation and improvement sequence

4.3.2 Over-control, under-control and control of processes

A process monitoring system can give rise to:

- a) *over-control*: action is taken when it should not be;
- b) *under-control*: action is not taken when it should be;
- c) *control*: action is taken when it should be and not taken when it should not be. A process is said to be under a state of (statistical) control when no special causes of variation are present. Variation can then be attributed purely to “common causes”. Control is not a natural state but it is an achievement, arrived at by elimination, one by one, by determined effort, of special cause variation. To achieve this it is essential to use statistical process control (SPC) charts that set out to provide a signal when a special cause of variation is present, and to avoid giving false signals when a special cause is not present.

Sometimes “assignable cause” is taken to be synonymous with “special cause”. However, a distinction should be recognized. In practice, not all special causes are assignable. A state of control does not imply that the common cause variation is large or small, within or outside of specification, but rather that it is predictable using statistical techniques.

4.3.3 The control chart

The control chart is a simple graphical tool that distinguishes between two types of variation:

- *special cause variation*: a source of variation that is not present all the time but which arises from specific circumstances;
- *common cause variation*: a source of variation that is inherent in a process over time.

When no special cause is present, the process is considered to be stable. It is then said to be in a state of statistical control. The capability of a stable attribute process can be calculated directly from the centre-line of the control chart. When a special cause is present, the process is said to be “out-of-control” and needs to be brought back under control.

These process states are readily determined from an attribute control chart. The attribute control chart is essentially a simple run chart with two added features, a centre-line and one or two control limits. The centre-line on an attribute control chart is normally the historical mean of the feature plotted. The control limit, or limits are lines on a control chart placed about the centre-line to evaluate whether, or not, the process is in a state of control. Typical criteria for assessing whether a control chart indicates an “out-of-control” situation are:

- a) any point outside of the control limits;
- b) any run of seven consecutive points above or below the centre-line;
- c) any run of seven consecutive points up or down;
- d) any obvious non-random patterns (based on technical and operational knowledge of the process).

4.3.4 Case study

Figure 3 shows a specific example of the use of an attribute control chart in process improvement. It relates to an underwear making-up (assembly) process.

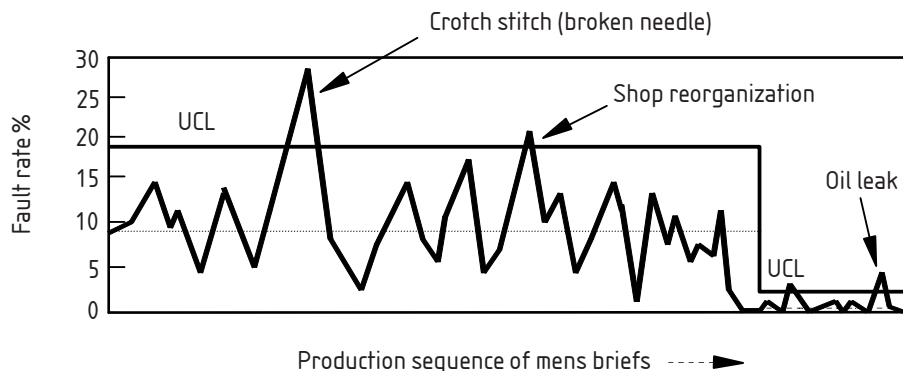


Figure 3 — Control chart for assembly of men's briefs

NOTE Out of control criteria are:

- any point outside the upper control limit (UCL);
- any run of seven consecutive points above or below the centre-line;
- any run of seven consecutive points up or down.

Figure 3 shows the following:

a) There are two quite different stages of performance.

b) The process was running initially at an overall fault rate of around 10 % (indicated by the dashed centre-line). This percentage provides a measure of overall process capability or performance. This is due to common causes endemic to the system of operation of the process: the accepted state of the art as presently performed. The value of 10 % was, and always had been, the expected level of performance and had been budgeted into the system. Hence, it was not considered a concern to operational management. The system had adapted to the situation by introducing aerospace standards of garment inspection with its attendant internal reject levels. As such, it was considered a premier division quality supplier to its major customer, a quality conscious retailer. However, the adverse effect of this state of affairs on company profit margin and product price was considerable.

c) During this period two points contravene the upper control limit (UCL). This indicates two undesirable "out-of-control" situations due to the presence of special causes. These causes were investigated and assigned to a broken needle and a sewing shop re-organization, as indicated on the control chart.

Management got very uptight about the broken needle situation, as a single machinist had worked with it during a whole period of overtime causing perforated crotches on many dozens of briefs. Whilst it is seen that the elimination of these special causes brought the process back into control it had no material effect on the reduction of overall faults.

d) Towards the end of the 10 % run, seven consecutive plotting points are below the original centre-line. This indicates a desirable out-of-control situation. It indicates that the process overall performance has changed significantly for the better. This was due to a management led shake-up and major training and personnel development initiative which gave rise to a reduction in common cause variation from a nearly 10 % fault rate to less than 1 %.

e) This significant improvement in process performance is reflected by a lowering of the upper control limit (UCL) resulting from the decrease in fault rate from 10 % to less than 1 %.

f) An out-of-control situation that causes a blip to nearly 5 % at the new level was caused by an oil leak from one machine causing staining of a number of garments.

This example illustrates why it is important to differentiate between special and common cause variation. The sporadic special cause variation is due to specific activities attributable to a machinist and direct support personnel caused by a weakness in operational control.

The initial overall performance of a 10 % fault rate, however, is a result of common causes endemic in the system, which is a management responsibility. Management should be judged on whether or not their words of dedication to never-ending improvement is actually showing through in improvements in the capability of processes evidenced by the simple but very revealing attribute data control chart.