

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

Part 4: Attribute inspection performance control and improvement

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- Association for Road Traffic Safety and Management (ARTSM)
- BAE Systems
- British Standards Society (BSS)
- Clay Pipe Development Association (CPDA)
- Federation of Small Businesses (FSB)
- Gauge and Tool Makers Association (GTMA)
- General Domestic Appliances Ltd.
- Institute of Quality Assurance
- National Physical Laboratory
- Royal Statistical Society

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Foreword

BS 5701-4:2003 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BS 5701:1980 and BS 2564:1955 and all four parts of BS 5701 together supersede BS 5701:1980 and BS 2564:1955, which are withdrawn.

BS 5701-1, 2 and 3 demonstrated the business benefits, versatility and usefulness of a very simple, yet powerful, pictorial control chart method for monitoring and interpreting qualitative data.

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 the control charting of measured data, refer to BS 5702-1.

The treatment of charting of qualitative data in BS 5701-1 is essentially at appreciation level. However, 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-based, 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.

With the monitoring of measurement data, decisions are made with calibrated instruments against objective criteria. A different situation prevails with attribute data. Decisions are frequently made by uncalibrated people against subjective criteria.

Much is made of the need for determining the ongoing capability of measuring instruments. It is standard practice to have stringent ongoing calibration requirements for instruments. Considerable attention is given to the need for measurement systems analysis in terms of resolution, accuracy and precision to verify, for example, conformance with exacting uncertainty, repeatability and reproducibility criteria. Yet, surprisingly, relatively little similar thrust takes place with the intrinsically much less reliable subjective decisions taken by people. Consequently, data used to construct control charts to monitor attribute processes frequently lack credibility. A similar situation occurs with acceptance sampling by attributes. How reliable are the decisions made? How valid are they? The statisticians classify such errors as Type 1 or Type 2. A Type 2 error may be caused by excessive caution, e.g. a jury or court who let a guilty defendant go free, whereas the Type 1 error can result from excessive zeal, e.g. the conviction of an innocent person. Similar conditions prevail in business: faulty items are sometimes accepted and good items are sometimes incorrectly rejected. The situation in business is compounded by the presence of subjective standards against which to make a judgement. In turn, this is exacerbated by a number of factors, such as time and commercial pressures, workplace environment and inspector aptitude, faculties, skills and knowledge.

BS 5701-4 takes the view that much can, and should, be done to improve decision-making in business when subjective judgements are involved. It provides guidelines by which this can be achieved.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 21 and a back cover.

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1 Scope

BS 5701-4 describes methods for enhancing the quality of attribute data used for monitoring, controlling and improving business processes.

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 Attribute inspection performance control and improvement

4.1 Overview

Effective monitoring of discrete data processes is highly dependent on the validity of judgements made on whether a particular attribute, signal or event is present or not.

Sometimes the decision is obvious, as objective criteria are present; for example, the number of incoming calls per minute and whether or not calls are answered within six rings.

Frequently, however, subjective judgements are involved, such as the determination whether a particular flaw or imperfection is present or not, or the need to discriminate between acceptable and non-acceptable products. In the case of subjective judgements it is particularly important that:

- a) the decision makers, the assessors, supervisors, inspectors, checkers, viewers, verifiers, auditors, and the like, have the appropriate aptitudes, faculties, knowledge and skills;
- b) “operational definitions” exist for the particular attributes or events in question;
- c) the influence of social and organizational factors and work-place design are taken into account;
- d) assessor calibration and assessment performance audits are conducted where applicable;
- e) attribute gauges have the required repeatability and accuracy.

4.2 Defining reference standards (establishing operational requirements)

Discrete data often arises in situations where some form of judgement is applied. To minimize variations in judgement, it is essential that clearly defined conformance criteria are established.

These criteria are often expressed in terms of “operational definitions” of characteristics. Such an operational definition:

- a) consists of a criterion to be applied, an examination and a decision: yes or no;
- b) requires a prescribed examination, a record of the result and a comparison of the result with the agreed criterion;
- c) should be communicable with the same meaning to one person as to another, yesterday, today and tomorrow.

An operational definition should not:

- i) quote exact values, e.g., round, flat, clean, pucker-free, 20 % fat (minimum, maximum, average?), 40 % wool (how distributed?);
- ii) use adjectives that have no communicable meaning e.g. uniform, safe, good or reliable.

Written standards for attributes are frequently difficult to develop and to apply without interpretations. In such cases, other methods are used, such as reference samples, photography, line diagrams and stereoscopic pictures. Often these are graded, e.g. “preferred”, “minimum acceptable” and “unacceptable”, or graded on a scale e.g. 1 to 5.

4.3 Influence of social and organizational factors and work-place design

4.3.1 Social and organizational factors

An inspector can be subjected to a number of social pressures from those providing him with products to inspect and those receiving them. Sometimes, these pressures balance out. Organizational structures should be such that rational objective criteria prevail. These should always aim to support rather than undermine the technical performance of the inspector.

Methods of payment can also influence inspector’s performance. Payment based on total throughput tends to give rise to a tendency to skim inspection. Payment based on the number of faults found can give rise to a possible increase in commission errors.

A further source of potential bias is the reject “norm” for a particular job, or in a particular department. It has been shown that it is possible for these norms to have a greater influence on the proportion of the parts rejected than the actual part quality level. These kinds of pressures can be alleviated by the provision of clear, objective acceptance standards, adequate instructions and training, effective inspection audit procedure and a sound organizational structure.

4.3.2 Inspection workstation design

4.3.2.1 General

Virtually all manual industrial inspection tasks rely heavily on vision, whether one is dealing with surface texture, colour, electrical or mechanical dimensions, correctness of assembly, etc. It is essential, therefore, if one is to ensure effective operating efficiency in terms of speed and accuracy, to take account of the significant factors affecting visual performance.

4.3.2.2 Lighting

4.3.2.2.1 Aspects of lighting

Aspects of lighting of particular relevance to visual inspection are:

- a) light level;
- b) luminance;
- c) contrast;
- d) colour;
- e) glare.

4.3.2.2.2 Light level

The rate of flow of luminous energy, (namely light) from a lamp is given in terms of lumens (lm).

For example, the light output from:

- a) A 100 W tungsten filament bulb is 1 200 lumens;
- b) An 80 W fluorescent lamp is 4 000 lumens.

Not all the light output from a lamp can be transferred to the viewing plane. The illumination of a work surface is expressed in terms of “lumens per unit area”. Lumens per square metre is termed “lux”. The order of service illumination proposed for different classes of inspection work is shown in Table 1.

Table 1 — Minimum light levels for different types of inspection

Type of inspection	Minimum service value of illumination lux
Minute detail (e.g. watches)	2 000 to 3 000
Small detail (e.g. gauging)	1 500 to 2 000
General viewing	500 to 1 000

4.3.2.2.3 Luminance

Luminance is the light emitted or reflected to the eye from an object, as opposed to illumination, which is the light falling onto it. Luminance is what is seen when inspecting an object, not illumination. The brightness (or luminance) of the object is important when considering the amount of light required for a particular viewing task. This luminance depends both on the level of illumination of the object and the proportion of that incident light which is reflected from the surface of the object. Two situations arise:

- a) non-specular surface – a perfectly diffusing surface, e.g. blotting paper that has the same luminance from all angles of view. Here:

Luminance = Illumination $\times$ Reflecting ratio

$$B = ER$$

This relationship is often used for surfaces that are not perfect diffusers:

- b) specular surfaces – bright polished surface (e.g. mirror, bright metal). Here, the luminosity will depend not only on the proportion of light reflected by the surface itself but by the image of a concentrated light source itself seen reflected in the surface. This luminance will have a directional property depending on the relative positions of the light source, observer and object being viewed.

Here, luminance is expressed as intensity in a specified direction/projected area as seen from that direction.

It should be appreciated, however, that specular surfaces also have reflectivity ratios in the same way as perfect diffusers. However, they introduce an additional complication, e.g. if one is inspecting sheets of polished aluminium, the light source itself or surroundings can be reflected in the surface at certain angles of view, thus impairing viewing efficiency.

4.3.2.2.4 Contrast

Regardless of the level of illumination, an object can only be seen by virtue of contrast with its background. There are two forms of contrast: brightness and colour. It is possible for two quite distinct colours to reflect the same amount of incident light – brightness contrast – yet be clearly distinguishable purely by their difference in hue.

4.3.2.2.5 Colour

A sensation of light in the human eye is caused by electromagnetic radiation within the wavelength band 400 nm to 750 nm. The eye is not equally sensitive to all wavelengths but has peak sensitivity at about 550 nm. Where inspection involves colour discrimination or comparison, it is essential that correct sources of illumination are used. If, for example, one inspects a red material under a fluorescent lamp deficient in red, the material will tend to grey. Colour, too, can be used in the sense of increasing contrast between an object e.g. pale blue cotton on a yellow blouse. Here, where both object and background have similar reflectivity and relatively low colour contrast, viewing conditions can be improved by using an orange light source. In general, if it is required to increase the contrast between two coloured surfaces, light which is deficient in the wavelength of the darker colour should be employed.

4.3.2.2.6 Glare

Glare, unwanted incident light in the visual field, reduces contrast and so the threshold of visual acuity.

Glare arises from natural (e.g. sun) or artificial (e.g. lamp) sources either directly or by reflection from the task itself or from surroundings. Glare is often classified as:

- a) *discomfort glare*: that which causes physical discomfort;
- b) *disability glare*: that which reduces visual effectiveness.

Glare can be reduced or avoided by:

- correct positioning of the display relative to light sources;
- elimination of reflected glare from bright images in the field of view;
- reducing possible phototropic effects. The eye tends to move to the brightest part of a visual field. This is known as phototropic effect – the involuntary turning towards light. It is distracting as well as being visually disadvantageous. If the adaption level of the eye is raised by the glare the eye becomes less sensitive to small differences in brightness.

4.3.2.3 Complexity of static visual display

Visual acuity falls off rapidly either side of the line of sight. This means that the eye is much more efficient in seeing a detail it is looking at than one just to the side. If the angle between a detail and the line of sight is just 20° visual acuity is decreased by 90 %. In other words, such a detail has to be 10 times as large to be seen as well.

Large complex stationary objects thus require to be scanned during the visual inspection cycle. Defect detection is basically a two-stage operation:

- a possible defect is seen some distance away from the line of sight;
- the eyes then home in on the suspect detail.

Visual inspection performance in detecting in stationary displays has been shown to be dependent on:

- the complexity of the display: where possible this should be simplified as much as possible – no information should be presented which is not essential;
- the method of scan: investigations have shown that performance variation detected between inspectors is often considerably influenced by the manner in which the scan is made;
- the peripheral acuity of the viewer: it has been demonstrated on a number of occasions that there is a tendency for peripherally located defects to be missed more often than centrally located ones. Inspectors with the best peripheral acuity tend to perform better in this respect.

4.3.2.3.1 Moving display

With a moving display:

- it is necessary for the eye to scan at the rate of movement of the display otherwise blurring will occur due to lack of visual acuity each side of centre. Hence good central rather than peripheral acuity is required particularly as rate of movement increases;
- there is usually less time for defect search. Hence, there is a need for both ensuring that scanning is done systematically and efficiently and that the span of the field at right angles to the line of travel (e.g. of the conveyor) is appropriate to the feed speed.

4.4 Inspector: faculties, aptitude and acquisition of skills and knowledge

4.4.1 Introduction

The generic term “inspector” embraces many job functions. For example:

- a) supervisory: organizational and administrative abilities;
- b) skilled inspection: technical knowledge and judgement;
- c) viewing: good vision: ability to maintain vigilance and make sound and quick decisions;
- d) gauging: tactile and visual ability: systematic;
- e) patrol/roving: intimate knowledge of process and operatives.

Selection procedures for inspectors should be based on a job analysis. They should include assessment of faculties, “skills”, aptitude and “temperament”. The first two can usually be readily assessed objectively using standard tests (e.g. visual acuity, reaction time, mechanical ability, manual dexterity). The latter two depend to an extent on subjective judgement. It is not an uncommon occurrence for persons to be engaged as inspectors without prior experience or training and then be looked upon as infallible.

In practice, if quantitative systematic measurements have not been taken of a particular operation, it is highly likely that the actual efficiency of inspection is much less than what it is considered to be. Speed and accuracy can often be significantly improved by initial instruction and training, performance monitoring and retraining as necessary.