BRITISH STANDARD

BS 7850-2: 1994
ISO 9004-4: 1993
Incorporating Amendment No. 1

Total quality management —

Part 2: Guidelines for quality improvement

UDC 658.56:006.83(083.13)

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Quality, Management and Statistics Standards Policy Committee (QMS/-) to Technical Committee QMS/22, upon which the following bodies were represented:

Associated Offices Technical Committee
Association of British Certification Bodies
Association of British Health-care Industries
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Water Services Association of England and Wales

West Midlands Enterprise Board

This British Standard, having been prepared under the direction of the Quality, Management and Statistics Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 15 March 1994

First published September 1992 Second edition March 1994

The following BSI references relate to the work on this standard:

Committee reference QMS/22

Draft for comment 92/89290 DC

ISBN 0 580 22865 7

Amendments issued since publication

Amd. No.	Date	Comments
8437	February 1995	Indicated by a sideline in the margin

Contents

National foreword

This Part of BS 7850 has been prepared under the direction of the Quality, Management and Statistics Standards Policy Committee. It is identical with ISO 9004-4:1993 *Quality management and quality system elements — Part 4: Guidelines for quality improvement*, including Technical Corrigendum 1, published by the International Organization for Standardization (ISO). It supersedes BS 7850-2:1992 which is withdrawn.

This Part of BS 7850 gives guidance on implementing continuous quality improvement within an organization.

The following Parts of BS 7850 have now been published:

— *Part 1: Guide to management principles*;

— *Part 2: Guidelines for quality improvement*.

Cross-references

International standard	Corresponding British Standard
ISO 8402:1986	BS 4778 *Quality vocabulary* Part 1:1987 *International terms* (Identical)

The British Standards corresponding to ISO 9004:1987 and ISO 9004-2:1991, listed in Annex B, are BS 5750-0.2:1987 and BS 5750-8:1991, respectively.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 24, an inside back cover and a back cover.

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Introduction

When implementing a quality system (e.g. as described in ISO 9004), the management of an organization should ensure that the system will facilitate and promote continuous quality improvement. A constant goal of management at all levels of an organization should be to strive for customer satisfaction and continuous quality improvement.

The quality of products and services is important for competitiveness. Continuous quality improvement is necessary to enhance an organization's competitive position. It should be emphasized that innovative strategies for the introduction of new product, service, or process technologies and continuous quality improvement all need to be considered.

The motivation for quality improvement comes from the need to provide increased value and satisfaction to customers. Every member of an organization should develop a conscious awareness that each process can be performed more effectively and more efficiently with less waste and resource consumption.

Increases in effectiveness and efficiency benefit customers, the organization and its members, and society in general. Continuous quality improvement enhances the ability of an organization to compete and the opportunity for its members to contribute, grow and excel.

1 Scope

This part of ISO 9004 gives management guidelines for implementing continuous quality improvement within an organization.

The ways of adopting and implementing these guidelines depend upon factors such as the culture, size, nature of the organization, the types of products or services offered, and the markets and customer needs served. Therefore, an organization should develop an improvement process suited to its own needs and resources.

This part of ISO 9004 is not for contractual, regulatory or certification use.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 9004. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 9004 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 8402:—[1)], *Quality management and quality assurance — Vocabulary*.

3 Definitions

For the purposes of this part of ISO 9004, the definitions given in ISO 8402 and the following definitions apply.

3.1
process
a set of inter-related resources and activities which transforms inputs into outputs

NOTE 1 Resources may include personnel, facilities, equipment, technology and methodology.

3.2
supply chain
a set of inter-related processes that accepts inputs from suppliers, adds value to these inputs, and produces outputs for customers

NOTE 2 Input and outputs can be either products or services.

NOTE 3 Customers and suppliers can be either internal or external to the organization.

NOTE 4 A unit of a supply chain is illustrated in Figure 1.

3.3
quality improvement
actions taken throughout the organization to increase the effectiveness and efficiency of activities and processes to provide added benefits to both the organization and its customers

3.4
quality losses
losses caused by not realizing the potential of resources in processes and activities

NOTE 5 Some examples of quality losses are the loss of customer satisfaction, loss of opportunity to add more value for the customer, the organization or society, as well as a waste of resources. Quality losses are a subset of quality costs (see **4.3**).

[1)] To be published. (Revision of ISO 8402:1986)

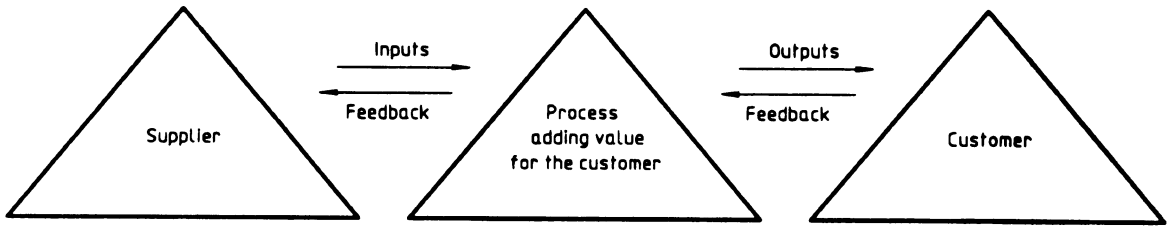


Figure 1 — A unit of a supply chain

3.5
preventive action
an action taken to eliminate the causes of a potential nonconformity, defect or other undesirable situation in order to prevent occurrence

3.6
corrective action
an action taken to eliminate the causes of an existing nonconformity, defect or other undesirable situation in order to prevent recurrence

NOTE 6 Actions for correcting process outputs include repair, rework or adjustment taken to rectify nonconforming, defective or other undesirable process outputs.

4 Fundamental concepts

4.1 Principles of quality improvement

The quality of an organization's products, services and other outputs is determined by the satisfaction of the customers who use them and results from the effectiveness and efficiency of the processes that create and support them.

Quality improvement is achieved by improving processes. Every activity or item of work in an organization comprises one or more processes.

Quality improvement is a continuous activity, aiming for ever higher process effectiveness and efficiency.

Quality-improvement efforts should be directed towards constantly seeking opportunities for improvement, rather than waiting for a problem to reveal opportunities.

Correcting process outputs reduces or eliminates a problem which has occurred. Preventive and corrective actions eliminate or reduce the causes of a problem, and hence eliminate or reduce any future occurrence. Thus, preventive and corrective actions improve the processes of an organization and are critical to quality improvement.

4.2 Environment for quality improvement

4.2.1 *Management responsibility and leadership*

The responsibility and leadership for creating the environment for continuous quality improvement belong to the highest level of management. Managers convey the leadership and commitment necessary for creating the environment for quality improvement by their own actions, constancy and deployment of resources. Managers lead quality improvement by communicating purpose and goals, by continuously improving their own work processes, by fostering an environment of open communication, teamwork and respect for the individual, and by enabling and empowering everyone in the organization to improve their work processes.

4.2.2 *Values, attitudes and behaviour*

The environment for quality improvement often requires a new set of shared values, attitudes and behaviour focusing on satisfying customer needs and setting ever more challenging goals. Values, attitudes and behaviour that are essential for continuous quality improvement include:

— focusing attention on satisfying the needs of both internal and external customers;

— involving the entire supply chain from suppliers to customers in quality improvement;

— demonstrating management commitment, leadership and involvement;

— emphasizing quality improvement as a part of everyone's job, either by teamwork or individual activities;

— addressing problems by improving processes;

— continuously improving all processes;

— establishing open communication with access to data and information;

— promoting teamwork and respect for the individual;

— making decisions based on the analysis of data.

4.2.3 *Quality-improvement goals*

Quality-improvement goals should be established throughout the organization. They should be closely integrated with the overall business goals and provide focus for increasing customer satisfaction and process effectiveness and efficiency. Quality-improvement goals should be defined so that progress can be measured. They should be clearly understandable, challenging and pertinent. Strategies to achieve these goals should be understood and agreed to by all who must work together to achieve them. Quality-improvement goals should be regularly reviewed and should reflect changing customer expectations.

4.2.4 *Communications and teamwork*

Open communication and teamwork remove organizational and personal barriers that interfere with effectiveness, efficiency and continuous improvement of processes. Open communication and teamwork should be extended throughout the whole supply chain, including suppliers and customers. Communication and teamwork require trust. Trust is essential if everyone is to be involved in identifying and following up on opportunities for improvement.

4.2.5 *Recognition*

The recognition process encourages actions consistent with values, attitudes and behaviour necessary for quality improvement (see **4.2.2**).

Successful recognition processes emphasize the development and growth of individuals and consider the factors which influence an individual's work performance (e.g. opportunity, organization, environment). Furthermore, successful recognition processes emphasize group performance and group recognition, and encourage frequent and informal feedback.

NOTE 7 Reward systems should be consistent with the recognition process. In particular, reward systems should avoid promoting destructive internal competition.

4.2.6 *Education and training*

On-going education and training are essential for everyone. Education and training programmes are important in creating and maintaining an environment for quality improvement. All members of an organization, including the highest levels of management, should be educated and trained in quality principles and practices and in the application of appropriate methods for quality improvement. This includes the use of quality-improvement tools and techniques (see Annex A). All education and training programmes should be reviewed for consistency with quality principles and practices. The effectiveness of education and training should be regularly assessed. Training separated from application is rarely effective (see **7.3**).

4.3 Quality losses

Opportunities to reduce quality losses guide quality-improvement efforts. Quality losses should be linked with the processes causing them. It is important at least to estimate even those quality losses which are difficult to measure, such as the loss of customer goodwill and the failure fully to utilize human potential. Organizations should reduce quality losses by using every opportunity to improve quality.

5 Managing for quality improvement

Although the application of any of the techniques described in Annex A will give some incremental improvement, their full potential can only be realized if they are applied and coordinated within a structured framework. This requires organizing, planning, measuring for quality improvement, and reviewing all quality-improvement activities.

5.1 Organizing for quality improvement

An effective way of organizing quality improvement identifies opportunities for quality improvement both vertically within the organizational hierarchy and horizontally in the processes that flow across organizational boundaries. In organizing for quality improvement, the following should be addressed:

— a means for providing policy, strategy, major quality-improvement goals, overall guidance, support and broad coordination of the organization's quality-improvement activities;

— a means of identifying cross-functional quality-improvement needs and goals and assigning resources to pursue them;

— a means to pursue quality-improvement goals by team activities within areas of direct responsibilities and authorities;

— a means for encouraging every member of the organization to pursue quality-improvement activities related to their work and for coordinating these activities;

— a means of reviewing and assessing the progress of quality-improvement activities.

Within the organizational hierarchy, responsibilities for quality improvement include:

— management processes such as defining the mission of the organization, strategic planning, clarifying roles and responsibilities, acquiring and assigning resources, providing education and training, and recognition;

— identification and planning of continuous improvement of the work processes of the organization;

— identification and planning of continuous improvement of the administrative-support processes of the organization;

— measurement and tracking of reduction of quality losses;

— development and maintenance of an environment that empowers, enables and charges all members of the organization continuously to improve quality.

Within the processes that flow across organizational boundaries, responsibilities for quality improvement include:

— defining and agreeing on the purpose of each process and its relationship with the objectives of the organization;

— establishing and maintaining communication among departments;

— identifying both internal and external customers of the process and determining their needs and expectations;

— translating customer needs and expectations into specific customer requirements;

— identifying suppliers to the process and communicating to them their customer needs and expectations;

— searching for process-improvement opportunities, allocating resources for improvement, and overseeing implementation of these improvements.

5.2 Planning for quality improvement

Quality-improvement goals and plans should be a part of an organization's business plan.

Management should set quality-improvement goals in the broadest sense including reducing quality losses. Plans should be developed within the business planning cycle to provide strategic guidance and direction for meeting these quality-improvement goals and implementing the quality policy. These plans should address the most important quality losses and should be deployed throughout all functions and all levels of the organization.

The development of quality-improvement plans should involve everyone in the organization, together with the suppliers and customers of the organization. Involving everyone greatly increases the opportunities for improvement.

Quality-improvement plans are often implemented through a set a specific quality-improvement projects or activities. Management should take care to monitor and control such implementation activities to ensure their integration into the overall goals and business plans of the organization.

Plans for quality improvements focus on newly identified opportunities and on areas where insufficient progress has been made. The planning process has inputs from all levels of the organization, from reviews of achieved results, and from customers and suppliers.

5.3 Measuring quality improvement

An organization should develop a measurement system that fits the nature of its operations. A system of objective measurements should be established for identifying and diagnosing improvement opportunities and for measuring the results of quality-improvement activities. A well-developed system includes measurements at unit, department, cross-functional and total organizational levels. The measurements should relate to quality losses associated with customer satisfaction, process efficiencies and societal losses.

a) Measures of quality losses associated with customer satisfaction may be based on information from surveys of current and potential customers, surveys of competing products and services, product or service performance records, changes in revenues, routine inspections by service personnel, information from sales and service staff, and customer complaints and claims.

b) Measures of quality losses associated with process efficiency may be based on labour, capital and material utilization, producing, sorting, correcting or scrapping unsatisfactory process output, process readjustments, waiting times, cycles times, delivery performance, unnecessarily redundant designs, size of inventories and statistical measures of process capability and process stability.

c) Measures of societal quality losses may be based on failure to realize human potential (e.g. as indicated by employee satisfaction surveys), damage caused by pollution and disposal of waste and depletion of scarce resources.

The phenomenon of variability is common to all measurements. Trends displayed by measurements should be interpreted statistically.

Measuring and tracking trends from a "baseline" of past performance are important, in addition to establishing and meeting numerically given targets. Measuring enhances problem identification based on fact.

The measurements should be reported and reviewed as an integral part of the management accounting and control practices of the organization. The people and organizations involved in the improvement process should be informed of their progress in terms that are meaningful and measurable from their perspective.

5.4 Reviewing quality-improvement activities

Regular reviews of quality-improvement activities should be conducted at all levels of management to ensure that:

— the organization for quality improvement is functioning effectively;

— plans for quality improvement are adequate and are being followed;

— measurements for quality improvement are appropriate and adequate, and indicate satisfactory progress;

— results of the review are fed into the next planning cycle.

Appropriate actions should be taken where any discrepancies have been identified.

6 Methodology for quality improvement

Quality-improvement benefits will accumulate steadily when an organization pursues quality-improvement projects and activities in a consistent, disciplined series of steps based on data collection and analysis.

6.1 Involving the whole organization

When an organization is well motivated and managed for quality improvement, a number of quality-improvement projects or activities of varied complexity will be continuously undertaken and implemented by all members and levels of the organization. Quality-improvement projects and activities will become a normal part of everyone's work and will vary from those necessitating cross-functional or management teams to those which will be selected and implemented by either individual members or teams.

A quality-improvement project or activity usually starts with the recognition of an improvement opportunity. This recognition can be based on measures of quality losses and/or on competitive comparisons (bench-marks) against organizations recognized as leaders in a particular field. Once defined, the quality-improvement project or activity progresses through a series of steps and is completed with the implementation of preventive or corrective actions taken on the process in order to reach and maintain the new, improved level of performance. As quality-improvement projects or activities are completed, new quality-improvement projects or activities are selected and implemented.

6.2 Initiating quality-improvement projects or activities

All members of the organization are involved in initiating quality-improvement projects or activities. The need, scope and importance of a quality-improvement project or activity should be clearly defined and demonstrated. The definition should include the relevant background and history, the associated quality losses and the current status, if possible expressed in specific, numerical terms. A person or a team, including the team leader, should be assigned to the project or activity. It is necessary to establish a schedule and allocate adequate resources. Provisions should be made for periodic reviews of scope, schedule, resource allocation and progress.

6.3 Investigating possible causes

The purpose of this step is to increase the understanding of the nature of the process to be improved by collection, validation and analysis of data. Data collection should always be carried out according to a carefully constructed plan. It is important to carry out the investigation of the possible causes with the utmost objectivity, without any preconceptions of what the causes or preventive or corrective actions might be. Decisions will then be based on facts.

6.4 Establishing cause-and-effect relationships

The data are analysed to gain insight into the nature of the process to be improved and to formulate possible cause-and-effect relationships. It is essential to distinguish between coincidence and cause-and-effect relationships. The relationships that appear to have a high degree of consistency with the data need to be tested and confirmed based on new data collected according to a carefully constructed plan.

6.5 Taking preventive or corrective actions

After cause-and-effect relationships are established, alternative proposals for preventive or corrective actions to address the causes should be developed and evaluated. Advantages and disadvantages of each proposal should be examined by the members of the organization who will be involved in implementing these actions. Successful implementation depends on the cooperation of all those involved.

NOTE 8 Quality improvements are obtained by taking preventive or corrective actions on the process to produce either more satisfactory outputs and/or reduce the frequency of unsatisfactory outputs. Relying solely on correcting process outputs such as repairing, reworking, or sorting perpetuates quality losses.

6.6 Confirming the improvement

After implementing preventive or corrective actions, appropriate data must be collected and analysed to confirm that an improvement has been made. The confirmatory data should be collected on the same basis as the data collected to investigate and establish cause-and-effect relationships. Investigations also need to be made for side effects, either desirable or undesirable, that may have been introduced.

If, after preventive or corrective actions are taken, the undesirable results continue to occur at approximately the same frequency as before, it will be necessary to redefine the quality-improvement project or activity by returning to the initiation step.

6.7 Sustaining the gains

After the quality improvement has been confirmed, it needs to be sustained. This usually involves a change of specifications and/or operating or administrative procedures and practices, necessary education and training, and making sure that these changes become an integral part of the job content of everyone concerned. The improved process then needs to be controlled at the new level of performance.

6.8 Continuing the improvement

If the desired improvement is obtained, new quality-improvement projects or activities should be selected and implemented. Since additional quality improvements are always possible, a quality-improvement project or activity may be repeated based on new objectives. It is advisable to set priorities, and to assign time limits for each quality-improvement project or activity. Time limits should not constrain effective quality-improvement activities.

NOTE 9 The "plan-do-check-act cycle" is used for continuous quality improvement. The quality-improvement methodology in this part of ISO 9004 emphasizes the check-act phases of this cycle.

7 Supporting tools and techniques

Decisions based on the analysis of situations and data play a leading role in quality-improvement projects and activities. Success of quality-improvement projects and activities is enhanced by proper application of tools and techniques developed for these purposes.

7.1 Tools for numerical data

Where possible, quality-improvement decisions should be based on numerical data. Decisions regarding differences, trends and changes in numerical data should be based on proper statistical interpretation.

7.2 Tools for non-numerical data

Some quality-improvement decisions may be based on non-numerical data. Such data play an important role in marketing, research and development, and in management decisions. Appropriate tools should be used to process properly this kind of data to transform them into useful information for decision making.

7.3 Training in applying tools and techniques

All members of the organization should receive training in applying quality-improvement tools and techniques to improve their work processes. Training separated from application is rarely effective. Annex A describes some of the numerous tools and techniques which have been developed. Table 1 lists these tools and techniques and their applications in quality improvement. Other tools or techniques may be appropriate for specific applications.

Table 1 — Tools and techniques for quality improvement

Sub-clause	Tools and techniques	Applications
A.1	Data-collection form	To gather data systematically to obtain a clear picture of the facts.
Tools and techniques for non-numerical data		
A.2	Affinity diagram	To organize into groupings a large number of ideas, opinions or concerns about a particular topic.
A.3	Benchmarking	To compare a process against those of recognized leaders to identify opportunities for quality improvement.
A.4	Brainstorming	To identify possible solutions to problems and potential opportunities for quality improvement.
A.5	Cause-and-effect diagram	To analyse and communicate cause-and-effect diagram relationships. To facilitate problem solving from symptom to cause to solution.
A.6	Flowchart	To describe an existing process. To design a new process.
A.7	Tree diagram	To show the relationships between a topic and its component elements.
Tools and techniques for numerical data		
A.8	Control chart	Diagnosis: to evaluate process stability. Control: to determine when a process needs to be adjusted and when it needs to be left as is. Confirmation: to confirm an improvement to a process.
A.9	Histogram	To display the pattern of variation of data. To communicate visually information about process behaviour. To make decisions about where to focus improvement efforts.
A.10	Pareto diagram	To display, in order of importance, the contribution of each item to the total effect. To rank improvement opportunities.
A.11	Scatter diagram	To discover and confirm relationships between two associated sets of data. To confirm anticipated relationships between two associated sets of data.

Annex A (normative)
Supporting tools and techniques

This annex introduces some of the most common tools and techniques for supporting quality improvement. The following tools and techniques are presented for analysing both non-numerical and numerical data. Data collection forms are presented first since they apply to both types of data. Tools for non-numerical data are then presented, followed by tools for numerical data.

Each tool or technique is presented in the following format.

a) **Application:** The use of the tool or technique in quality improvement.

b) **Description:** A brief description of the tool or technique.

c) **Procedure:** The step-by-step procedure for using the tool or technique.

d) **Example:** An example of use is given for some of the tools or techniques.

A.1 Data-collection form

A.1.1 *Application*
A data-collection form is used to gather data systematically to obtain a clear picture of the facts.

A.1.2 *Description*
The data-collection form is a template for collecting and recording data. It promotes the collection of data in a consistent manner and facilitates analysis.

A.1.3 *Procedure*

a) Establish the specific purpose of collecting these data (the questions to be addressed).

b) Identify the data required to achieve the purpose (address the questions).

c) Determine how the data will be analysed and by whom (statistical tools).

d) Construct a form to record the data. Provide a place to record information about

— who collected the data;

— where, when and how the data were collected.

e) Pretest the form by collecting and recording some data.

f) Review and revise the form if necessary.

A.1.4 *Example*
The number of reproduction defects of each type attributable to each cause may be collected on a form as given in Table A.1.

A.2 Affinity diagram

A.2.1 *Application*
An affinity diagram is used to organize into groupings a large number of ideas, opinions or concerns about a particular topic.

Description
When large numbers of ideas, opinions or other concerns about a particular topic are being collected, this tool organizes the information into groupings based on the natural relationships that exist among them. The process is designed to stimulate creativity and full participation. It works best in groups of limited size (a maximum of eight members is recommended) in which members are accustomed to working together. This tool is often used to organize ideas generated by brainstorming.

Table A.1 — Data-collection form

Causes of defects	Types of defect				
	Missing pages	Muddy copies	Showthrough	Pages out of sequence	Total
Machine jams					
Humidity					
Toner					
Condition of originals					
Other (specify)					
				TOTAL	
Who collected the data: Date: Where: How:					

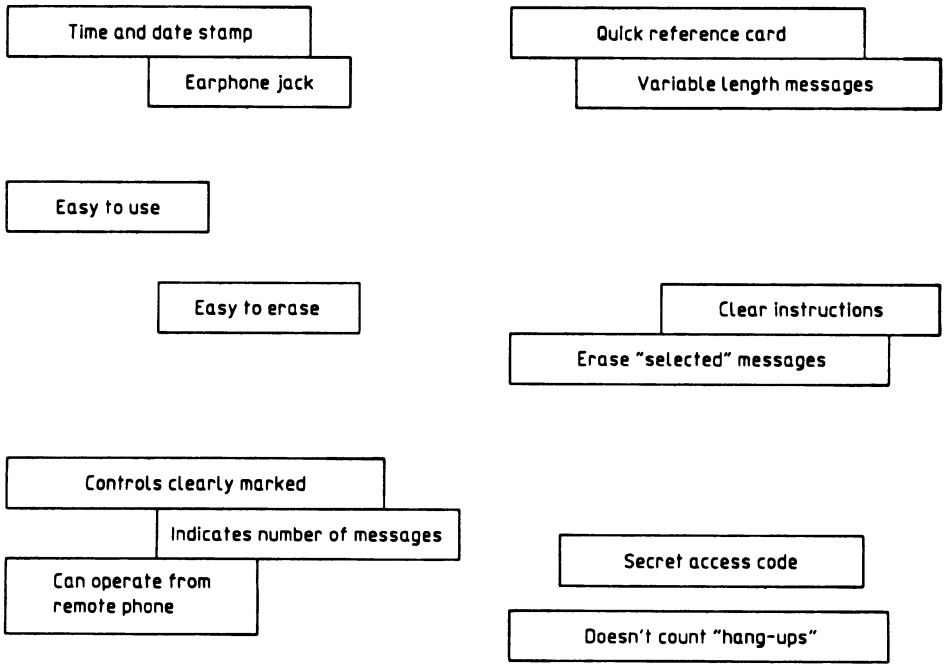


Figure A.1 — Random display as per step c) of A.2.2

A.2.2 *Procedure*

a) State the topic to be studied in broad terms (details may prejudice the response).

b) Record as many as possible individual ideas, opinions or concerns on cards (one per card).

c) Mix the cards and spread them randomly on a large table.

d) Group related cards together as follows:

— sort cards that seem to be related into groups;

— limit number of groupings to ten without forcing single cards into groups;

— locate or create a header card that captures the meaning of each group;

— place this header card on top.

e) Transfer the information from cards onto paper, organized by groupings.

A.2.3 Example

Requirements for a telephone answering machine are shown in Figure A.1 and Table A.2.

Table A.2 — Data organized by grouping as per step e) of A.2.2

Variable length messages Time and date stamp Doesn't count "hang-ups" Indicates number of messages	Incoming messages
Secret access code Earphone jack	Privacy
Clear instructions Quick reference card	Instructions
Controls clearly marked Easy to use Can operate from remote phone	Controls
Easy to erase Erase "selected" messages	Erasing

A.3 Benchmarking

A.3.1 *Application*

Benchmarking is used to compare a process against those of recognized leaders to identify opportunities for quality improvement.

A.3.2 *Description*

Benchmarking compares processes and performances of products and services against those of recognized leaders. It allows the identification of targets and the establishment of priorities for preparation of plans that will lead to competitive advantages in the marketplace.

A.3.3 *Procedure*

a) Determine the items to benchmark:

— the items should be key characteristics of processes and their outputs;

— process-output benchmarks should be directly related to customer needs.

b) Determine who to benchmark against:

— typical organizations may be direct competitors and/or non-competitors who are recognized leaders in the item of interest.

c) Collect data:

— data on process performance and customer needs may be obtained by such means as direct contact, surveys, interviews, personal and professional contacts, and technical journals.

d) Organize and analyse data:

— the analysis is directed towards establishing best practice targets for all relevant items.

e) Establish benchmarks:

— identify opportunities for quality improvement based on customer needs and competitor and non-competitor performances.

A.4 Brainstorming

A.4.1 *Application*

Brainstorming is used to identify possible solutions to problems and potential opportunities for quality improvement.

A.4.2 *Description*

Brainstorming is a technique for tapping the creative thinking of a team to generate and clarify a list of ideas, problems or issues.

A.4.3 *Procedure*

Two phases are involved.

a) **The generation phase**

The facilitator reviews the guidelines for brainstorming and the purpose of the brainstorming session, then the team members generate a list of ideas. The objective is to generate as many ideas as possible.

b) **The clarification phase**

The team reviews the list of ideas to make sure that everyone understands all the ideas. The evaluation of ideas will occur when the brainstorming session is completed.

Guidelines for brainstorming include:

— a facilitator is identified;

— the purpose of the brainstorming session is clearly stated;

— each team member takes a turn in sequence, stating a single idea;

— where possible, team members build on others' ideas;

— at this stage, ideas are neither criticized nor discussed;

— ideas are recorded where all team members can see them;

— this process continues until no more ideas are generated;

— All ideas are reviewed for clarification.

A.5 Cause-and-effect diagram

A.5.1 *Application*

A cause-and-effect diagram is used to

— analyse cause-and-effect relationships;

— communicate cause-and-effect relationships; and

— facilitate problem solving from symptom to cause to solution.

A.5.2 *Description*

The cause-and-effect diagram is a tool used for thinking through and displaying relationships between a given effect (e.g. variations in a quality characteristic) and its potential causes. The many potential causes are organized into major categories and sub-categories so that the display resembles a skeleton of a fish. Hence, the tool is also known as a fishbone diagram.

A.5.3 *Procedure*

a) Define the effect clearly and concisely.

b) Define the major categories of possible causes.

Factors to consider include:

— data and information systems,
— environment,
— equipment,
— materials,
— measurements,
— methods,
— people.

c) Begin to construct the diagram, defining the effect in a box on the right-hand side and positioning major categories as "feeders" to the "Effect" box (see Figure A.2).

d) Develop the diagram by thinking through and writing in all next-level causes and continue this procedure to levels of higher order. A well-developed diagram will have no branches of less than two levels, and many with three or more levels (see Figure A.3).

e) Select and identify a small number (3 to 5) of highest-level causes that are likely to have the greatest influence on the effect and require further action, such as collection of data, control effort, etc.

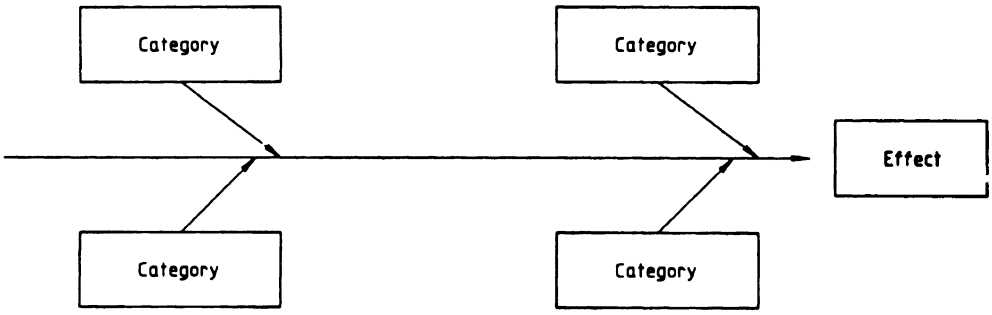


Figure A.2 — Initial cause-and-effect diagram

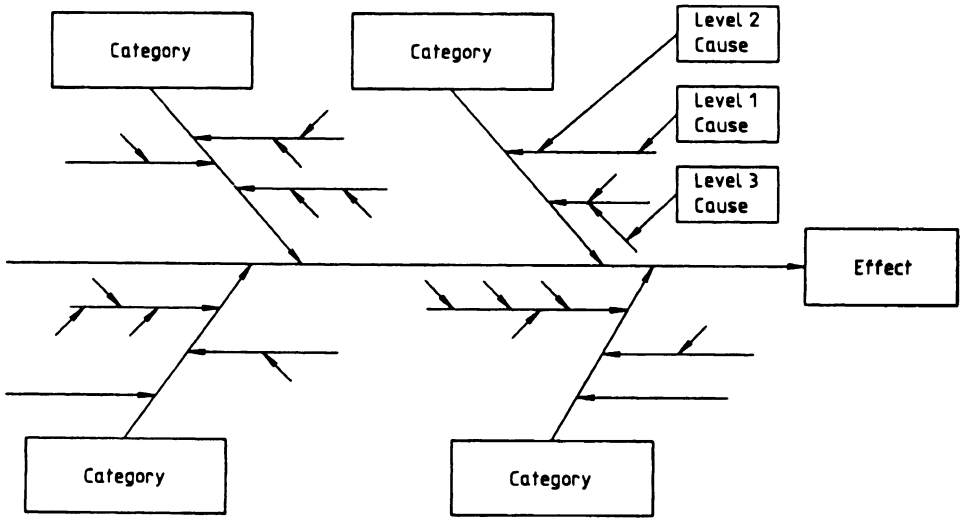


Figure A.3 — Development of cause-and-effect diagram

NOTE 10 An alternative method for constructing a cause-and-effect diagram is to brainstorm all possible causes, then organize them into categories and sub-categories using an affinity diagram.

NOTE 11 In certain cases, listing the main steps of a process as major categories may be advantageous; e.g. when the flow of a process is the effect considered for improvement. Flow-charting is often useful in defining these steps.

NOTE 12 Once constructed, the diagram can become a "living tool" with further refinements being introduced as new knowledge and experience are gained.

NOTE 13 The diagram is often constructed by groups, but it may be constructed by individuals possessing appropriate process knowledge and experience.

A.5.4 *Example*

Figure A.4 shows a cause-and-effect diagram for poor-quality photocopying.

A.6 Flowchart

A.6.1 *Application*

A flowchart is used to

— describe an existing process, or

— design a new process.

A.6.2 *Description*

A flowchart is a pictorial representation of the steps in a process, useful for investigating opportunities for improvement by gaining a detailed understanding of how the process actually works. By examining how various steps in a process relate to each other, one may often uncover potential sources of troubles. Flowcharts can be applied to all aspects of any process from the flow of materials to the steps in making a sale or servicing a product.

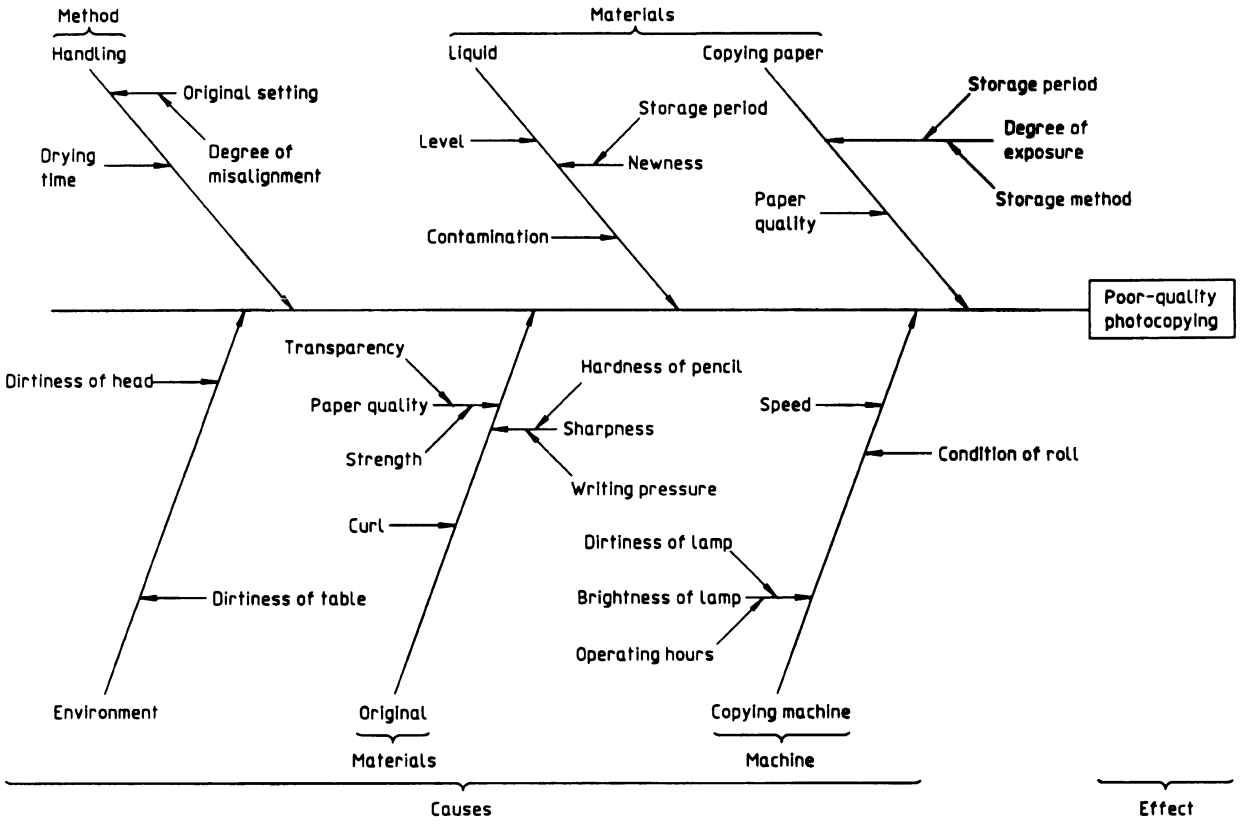


Figure A.4 — Example of a cause-and-effect diagram

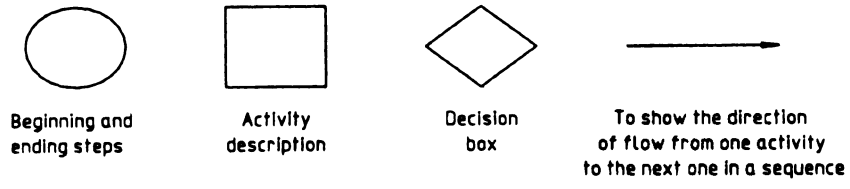


Figure A.5 — Flowchart symbols

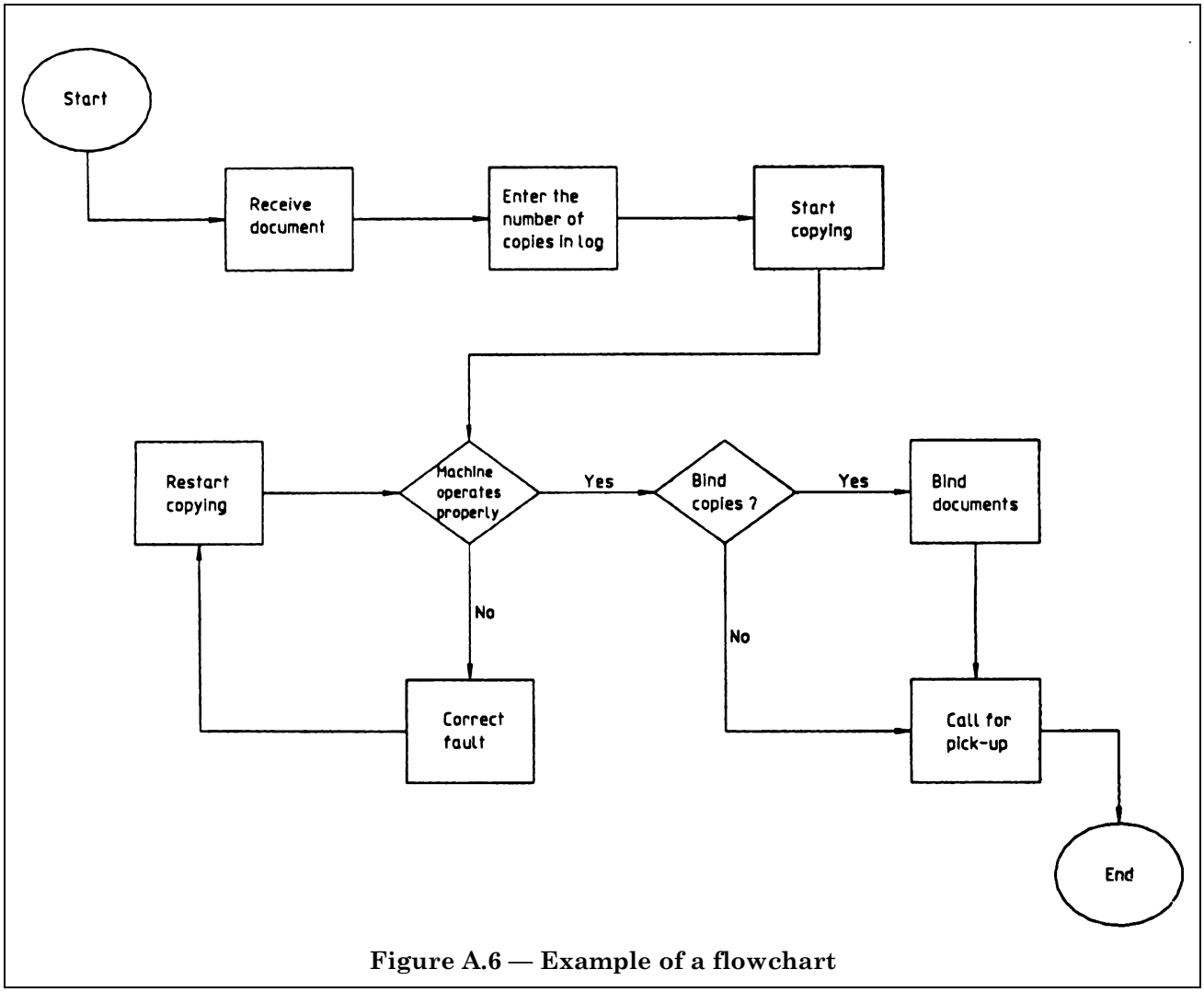


Figure A.6 — Example of a flowchart

Flowcharts are constructed with easily recognized symbols. Commonly used symbols are illustrated in Figure A.5.

A.6.3 *Procedure*

A.6.3.1 *Describing an existing process*

a) Identify the start and end of the process.

b) Observe the entire process from start to end.

c) Define the steps in the process (activities, decisions, inputs, outputs).

d) Construct a draft flowchart to represent the process.

e) Review the draft flowchart with the people involved in the process.

f) Improve the flowchart based on this review.

g) Verify the flowchart against the actual process.

h) Date the flowchart for future reference and use. (It serves as a record of how the process actually operates and can also be used to identify opportunities for improvement.)

A.6.3.2 *Designing a new process*

a) Identify the start and end of the process.

b) Visualize the steps to be made in the process (activities, decisions, inputs, outputs).

c) Define the steps in the process (activities, decisions, inputs, outputs).

d) Construct a draft flowchart to represent the process.

e) Review the draft flowchart with the people expected to be involved in the process.

f) Improve the flowchart based on this review.

g) Date the chart for future reference and use. (It serves as a record of how the process is designed to operate, and can also be used to identify opportunities for improvements to the design.)

A.6.4 *Example*

The flowchart shown in Figure A.6 represents the process for reproducing a document.

A.7 Tree diagram

A.7.1 *Application*

A tree diagram is used to show the relationships between a topic and its components elements.

A.7.2 *Description*

A tree diagram systematically breaks down a topic into its component elements. Ideas generated by brainstorming and graphed or clustered with an affinity diagram can be converted into a tree diagram to show logical and sequential links. This tool can be used in planning and problem solving.

A.7.3 *Procedure*

a) Clearly and simply state the topic to be studied.

b) Define the major categories of the topic. (Brain-storm or use the header cards from the affinity diagram.)

c) Construct the diagram by placing the topic in a box on the left-hand side. Branch the major categories laterally to the right.

d) For each major category, define the component elements and any sub-elements.

e) Laterally branch to the right the component elements and sub-elements for each major category.

f) Review the diagram to ensure that there are no gaps in either sequence or logic.

A.7.4 *Example*

The tree diagram shown in Figure A.7 represents a telephone answering machine.

A.8 Control chart

A.8.1 *Application*

A control chart is used for the following purposes.

a) Diagnosis: to evaluate process stability.

b) Control: to determine when a process needs to be adjusted and when it is to be left as is.

c) Confirmation: to confirm an improvement to a process.

A.8.2 *Description*

A control chart is a tool for distinguishing variations due to assignable or special causes from the chance variations inherent in the process. Chance variations repeat randomly within predictable limits. Variations due to assignable or special causes indicate that some factors affecting the process need to be identified, investigated and brought under control.

The construction of control charts is founded in mathematical statistics. Control charts use operating data for establishing limits within which future observations are to be expected if the process remains unaffected by assignable or special causes. Appropriate International Standards (e.g. ISO 7870 and ISO 8258, see Annex B) should be consulted for further information on control charts.

NOTE 14 A great variety of control methods exist that can be applied to all kinds of measurable or countable characteristics of a process, product or any output. An organization should acquire appropriate training and develop an adequate expertise on how to construct and apply control charts.

A.8.3 *Procedure*

a) Select the characteristics for application of a control chart.

b) Select the appropriate type of control chart.

c) Decide on the sub-group (a small collection of items, within which variations are assumed to be due to chance alone), its size, and the frequency of sub-group sampling.

d) Collect and record data on at least 20 to 25 sub-groups, or use previously recorded data.

e) Calculate statistics which characterize each sub-group sample.

f) Calculate control limits based on the statistics from sub-group samples.

g) Construct a chart and plot the sub-group statistics.

h) Examine the plot for points outside control limits and for patterns indicating the presence of assignable (special) causes.

i) Decide on future action.

A.8.4 *Example*

A new machine was installed for filling containers with 5 kg of product. The overfill, in grams, was deemed to be the important characteristic to be investigated and controlled by means of a control chart.

a) Mean ($\bar{X}$) and range (R) charts were selected for this purpose.

b) The subgroup was defined as five consecutive filled containers taken off the machine at hourly intervals.

c) Data were collected on 25 subgroups and recorded, preserving the order of observations.

d) Sample statistics $\bar{X}$ (mean of five observations) and R (range of five observations) were calculated for each subgroup sample.

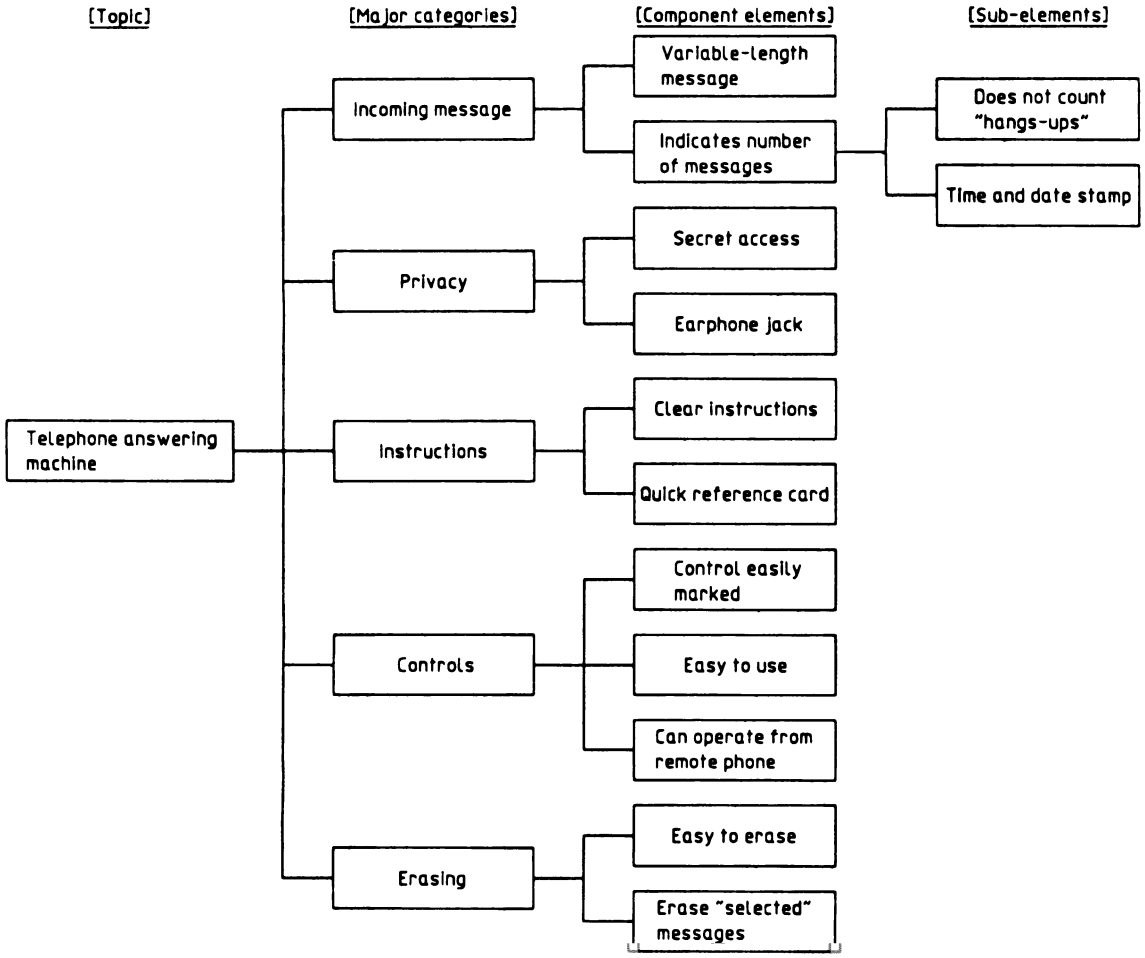


Figure A.7 — Example of a tree diagram

e) By applying appropriate formulae (see ISO 8258), the centrelines (CL) and the upper (UCL) and lower (LCL) control limits for $\overline{X}$ and R were calculated.

f) The charts were constructed.

g) Examination of the control charts showed no points outside the control limits, and no patterns of points indicating lack of randomness or presence of assignable causes. Hence, the process was judged to be repeating predictably, i.e. in a state of statistical control.

h) It was decided to continue sampling and charting the overfill in the same manner, and not to make any adjustments to the process, unless the control chart indicated an intrusion of an assignable cause. (If control chart data were available for the old process of filling the containers, a decision could be made about the degree of improvement the new machinery has brought about.)

The data given in Table A.3 are plotted to give the control chart shown in Figure A.8.

Table A.3 — Overfill data and sample statistics ($\bar{X}$, R)

Values are in grams

Sub-group No.	X_1	X_2	X_3	X_4	X_5	X	$\bar{X}$	R
1	47	32	44	35	20	178	35,6	27
2	19	37	31	25	34	146	29,2	18
3	19	11	16	11	44	101	20,2	33
4	29	29	42	59	38	197	39,4	30
5	28	12	45	36	25	146	29,2	33
6	40	35	11	38	33	157	31,4	29
7	15	30	12	33	26	116	23,2	21
8	35	44	32	11	38	160	32,0	33
9	27	37	26	20	35	145	29,0	17
10	23	45	26	37	32	163	32,6	22
11	28	44	40	31	18	161	32,2	26
12	31	25	24	32	22	134	26,8	10
13	22	37	19	47	14	139	27,8	33
14	27	32	12	38	30	149	29,8	26
15	25	40	24	50	19	158	31,6	31
16	7	31	23	18	32	111	22,2	25
17	38	0	41	40	37	156	31,2	41
18	35	12	29	48	20	144	28,8	36
19	31	20	35	24	47	157	31,4	27
20	12	27	38	40	31	148	29,6	28
21	52	42	52	24	25	195	39,0	28
22	20	31	15	3	28	97	19,4	28
23	29	47	41	32	22	171	34,2	25
24	28	27	22	32	54	163	32,6	32
25	42	34	15	29	21	141	28,2	27
						Total	746,6	686
						Average	$\bar{\bar{X}} = 29{,}86$ $\bar{R} = 27{,}44$	

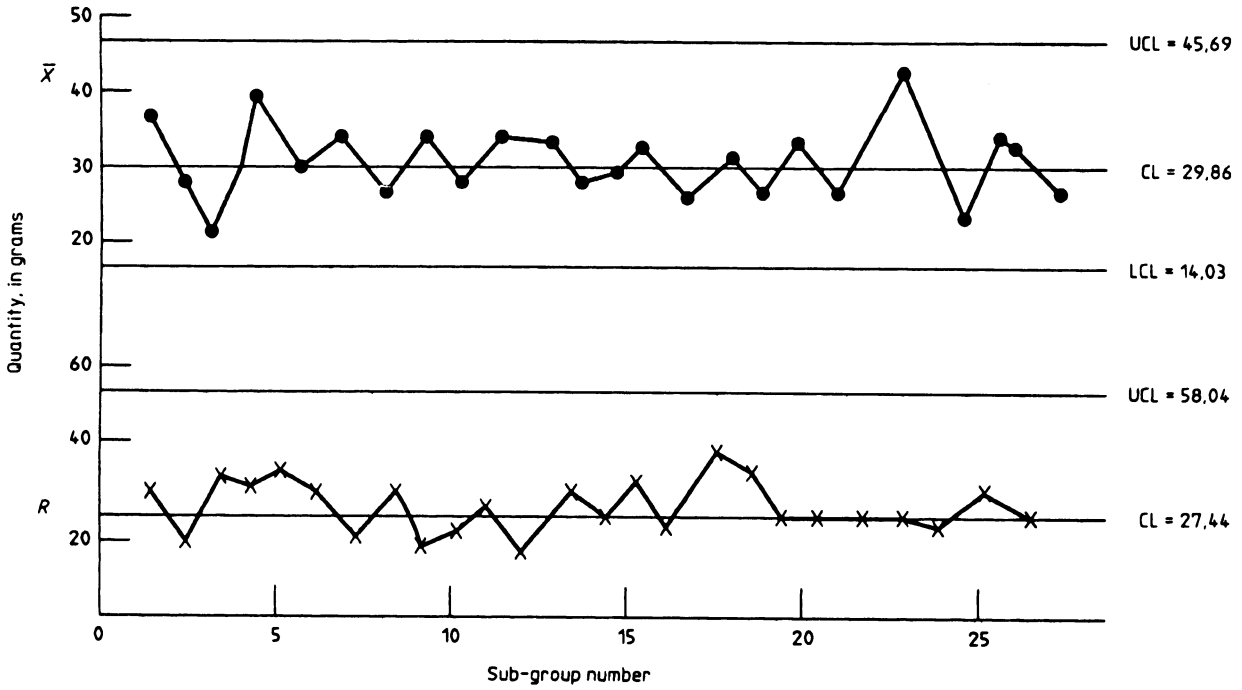


Figure A.8 — $\bar{X}$ and R charts for overfill data

A.9 Histogram

A.9.1 *Application*

A histogram is used to

— display the pattern of variation;

— communicate visually information about process behaviour;

— make decisions about where to focus improvement efforts.

A.9.2 *Description*

The data are displayed as a series of rectangles of equal width and varying heights. The width represents an interval within the range of data. The height represents the number of data values within a given interval. The pattern of varying heights shows the distribution of data values. Figure A.9 shows four commonly occurring patterns of variation. By examining these patterns, one can obtain insights into process behaviour.

A.9.3 *Procedure*

a) Collect the data values.

b) Determine the range of the data by subtracting the smallest data value from the largest.

c) Determine the number of intervals in the histograms (often between 6 and 12) and divide the range [step b)] by the number of intervals to determine the width of each interval.

d) Mark the horizontal axis with the scale of the data values.

e) Mark the vertical axis with the frequency scale (number or percent of observations).

f) Draw the height of each interval equal to the number of data values that fall within the interval.

NOTE 15 It is possible to design a data-collection form so that a histogram is generated as the data are collected. Such a form is often called a “tally sheet”.

A.9.4 *Example*

The histogram shown in Figure A.10 represents the overfill data for the control chart example (Table A.3).

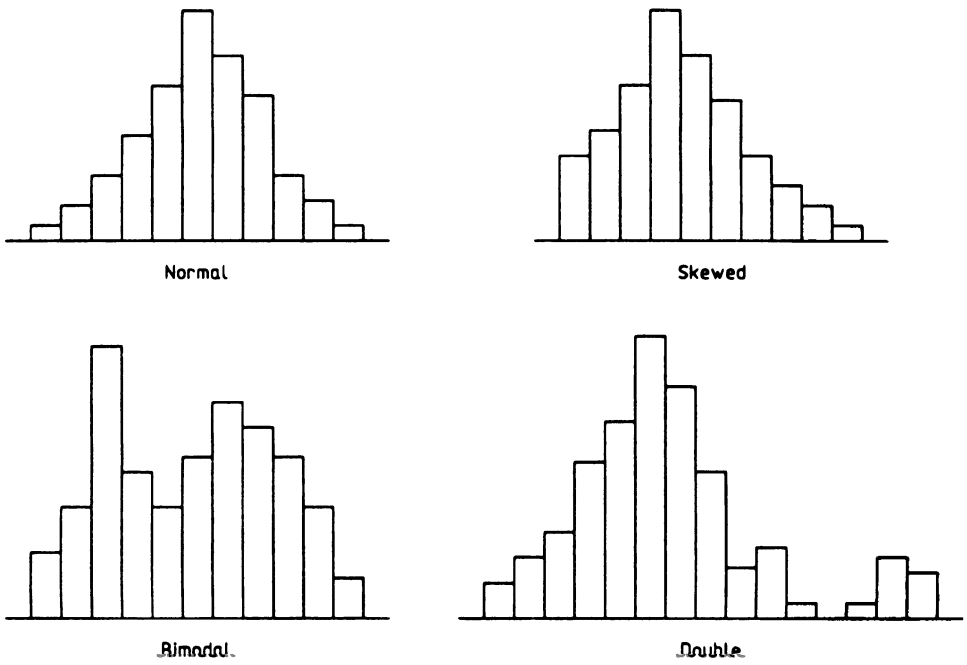


Figure A.9 — Commonly occurring patterns in histograms

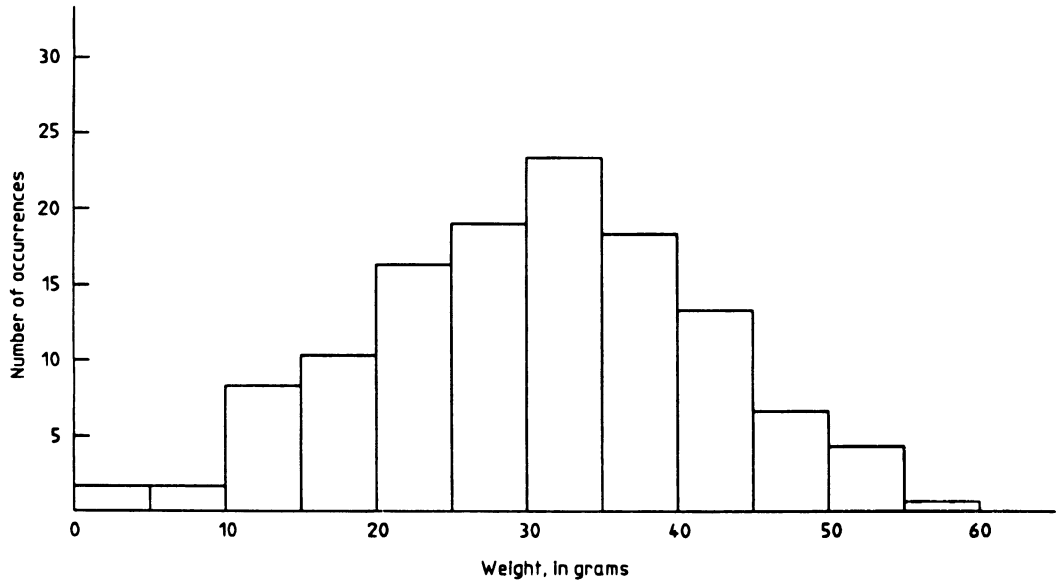


Figure A.10 — Example of a histogram

A.10 Pareto diagram

A.10.1 *Application*

A Pareto diagram is used to

— display the contribution of each item to the total effect in order of importance;

— rank improvement opportunities.

A.10.2 *Description*

A Pareto diagram is a simple graphical technique for ranking items from the most frequent to the least frequent. The Pareto diagram is based on the Pareto principle, which states that just a few of the items often account for most of the effect. By distinguishing the most important items from the less important ones, the greatest improvement will be obtained with the least effort.

The Pareto diagram displays, in decreasing order, the relative contribution of each item to the total effect. The relative contribution may be based on the number of occurrences, the cost associated with each item, or other measures of impact on the effect. Blocks are used to show the relative contribution of each item. A cumulative frequency line is used to show the cumulative contribution of items.

A.10.3 *Procedure*

a) Select the items to be analysed.

b) Select the unit of measurement for analysis, such as the number of occurrences, costs or another measure of impact.

c) Select the time-period of the data to be analysed.

d) List the items from left to right on the horizontal axis in order of decreasing magnitude of the unit of measurement. Categories containing the least items can be combined into an "other" category. Place this category on the extreme right-hand side.

e) Construct two vertical axes, one at each end of the horizontal axis. The left-hand scale should be calibrated in the unit of measurement, and its height must equal the sum of the magnitudes of all items. The right-hand scale must have the same height and is calibrated from 0 to 100 %.

f) Above each item, draw a rectangle whose height represents the magnitude of the unit of measurement for that item.

g) Construct the cumulative frequency line by summing the magnitudes of each item from left to right (see Figure A.11).

h) Use the Pareto diagram to identify the most important items for quality improvement.

A.10.4 *Example*

Figure A.11 represents a Pareto diagram for reports of troubles with telephones.

A.11 Scatter diagram

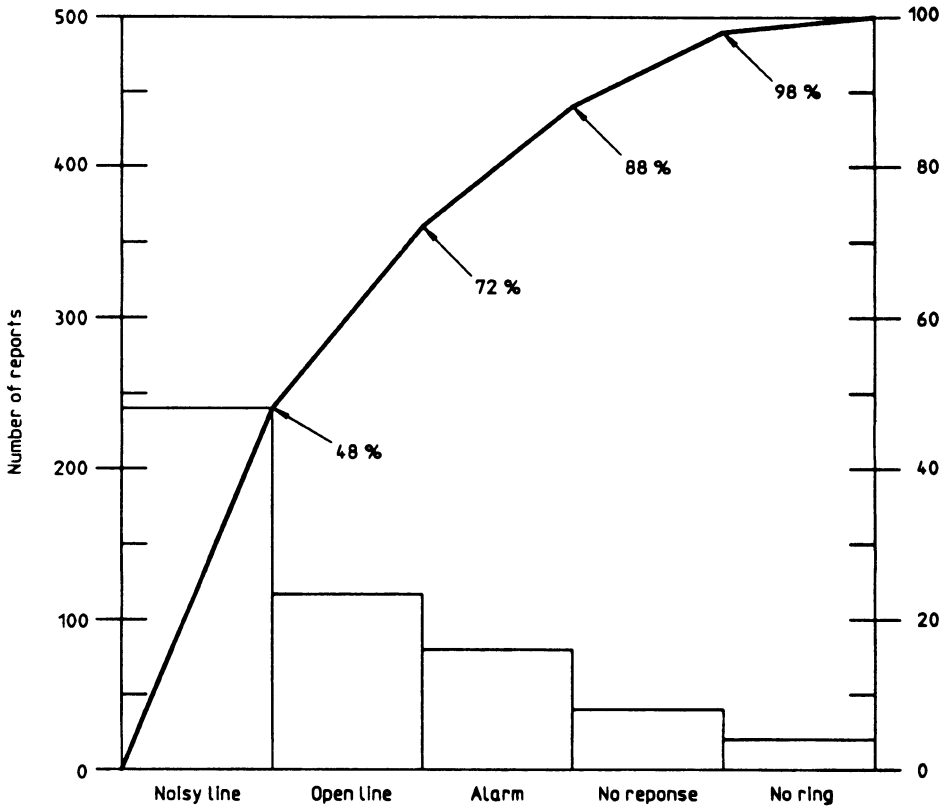
A.11.1 *Application*

A scatter diagram is used to discover and display relationships between two associated sets of data, and to confirm anticipated relationships between two associated sets of data.

A.11.2 *Description*

A scatter diagram is a graphical technique for studying relationships between two associated sets of data which occur in pairs [e.g. *(x, y)*, one from each set]. The scatter diagram displays the pairs as a cloud of points. Relationships between the associated sets of data are inferred from the shape of the clouds. A positive relationship between x and y means increasing values of x are associated with increasing values of y. A negative relationship means increasing values of x are associated with decreasing values of y.

Six commonly occurring shapes of these clouds are shown in Figure A.12. By examining these shapes one can obtain insights into the relationships between these sets of data.



NOTE The above diagram shows that noisy lines and open lines account for 72 % of the telephone-trouble reports and that these indicate the greatest opportunities for improvement.

Figure A.11 — Example of a Pareto diagram

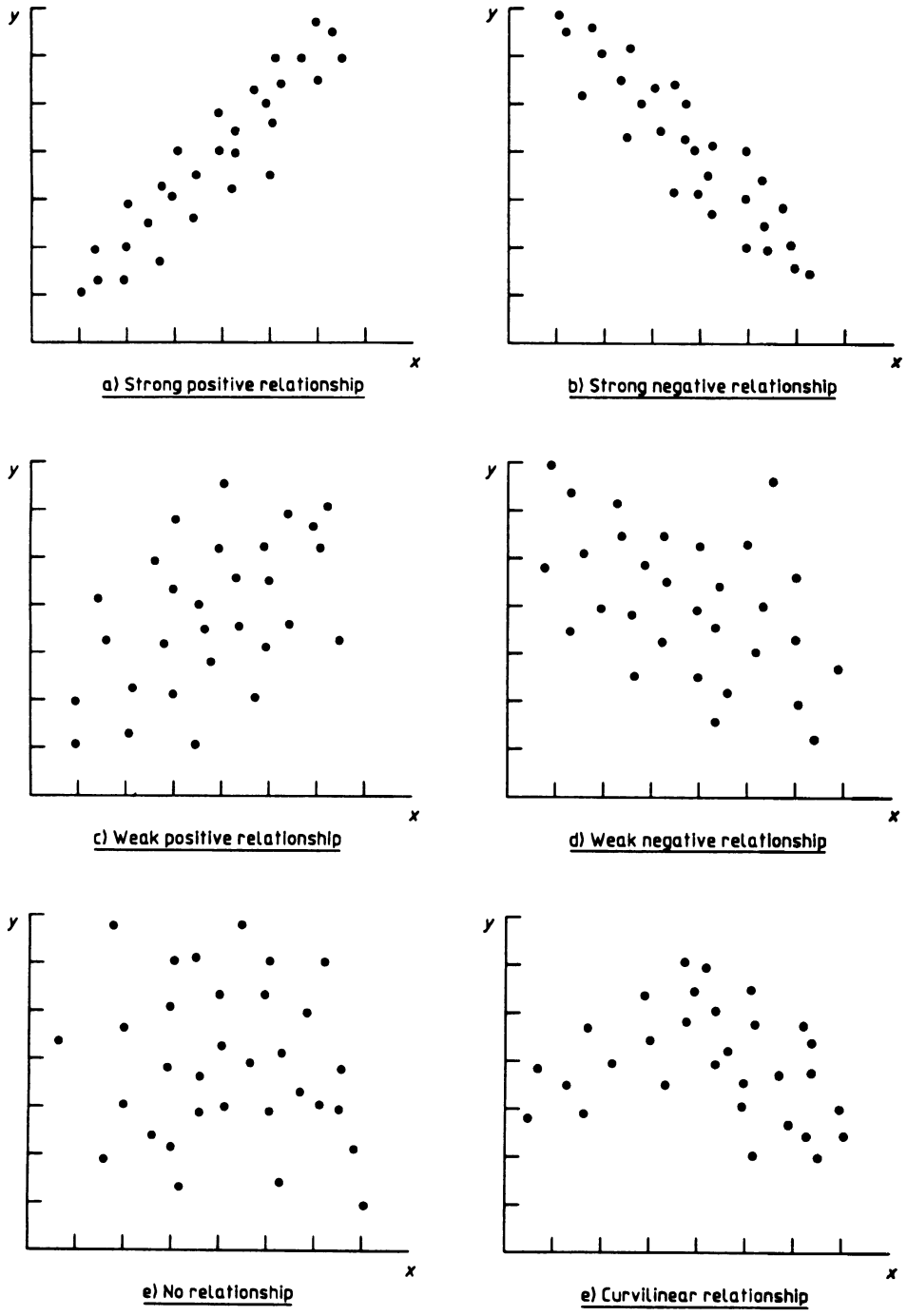


Figure A.12 — Commonly occurring scatter diagrams

A.11.3 *Procedure*

a) Collect paired data *(x, y)* from two associated sets of data whose relationship is to be studied. It is desirable to have about 30 pairs of data.

b) Label the x and y axes.

c) Find the minimum and maximum values for both *x* and *y* and use these values to scale the horizontal *(x)* and vertical *(y)* axes. Both axes should be of about equal length.

d) Plot the paired *(x, y)* data. When two pairs of data have the same values, either draw concentric circles around the plotted point or plot the second point nearby.

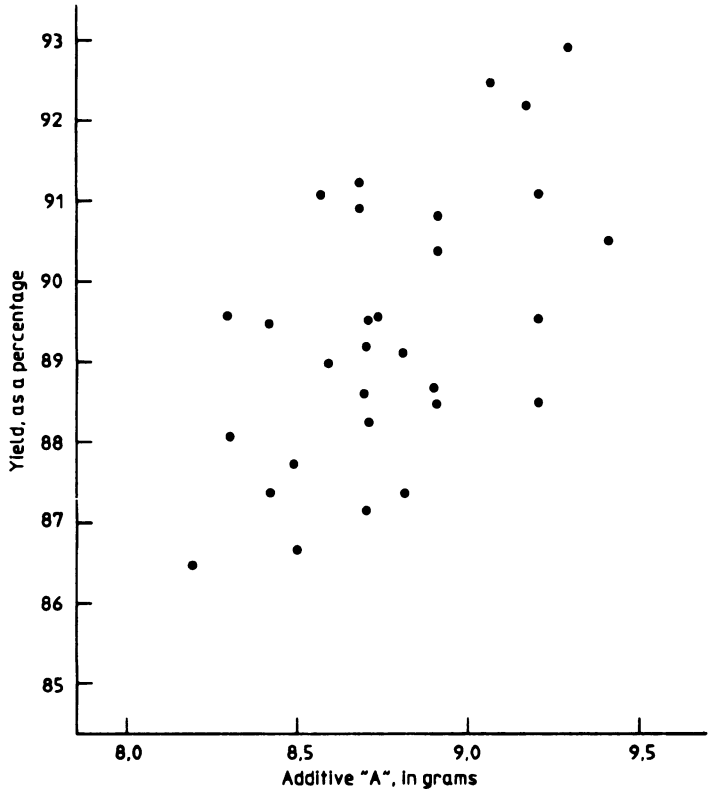
e) Examine the shape of the cloud of points to discover the types and strengths of relationships.

A.11.4 *Example*

Data for the amount of an additive and the resultant yield are given in Table A.4. The scatter diagram plotted from these data is shown in Figure A.13.

Table A.4 — Amount of additive "A" and associated yield

Batch No.	Additive "A" g	Yield %	Batch No.	Additive "A" g	Yield %
1	8,7	88,7	16	8,4	89,4
2	9,2	91,1	17	8,2	86,4
3	8,6	91,2	18	9,2	92,2
4	9,2	89,5	19	8,7	90,9
5	8,7	89,6	20	9,4	90,5
6	8,7	89,2	21	8,7	89,6
7	8,5	87,7	22	8,3	88,1
8	9,2	88,5	23	8,9	90,8
9	8,5	86,6	24	8,9	88,6
10	8,3	89,6	25	9,3	92,8
11	8,6	88,9	26	8,7	87,2
12	8,9	88,4	27	9,1	92,5
13	8,8	87,4	28	8,7	91,2
14	8,4	87,4	29	8,7	88,2
15	8,8	89,1	30	8,9	90,4



NOTE — This scatter diagram shows a weak-to-positive relationship between the amount of the additive "A" and the resultant yield.

Figure A.13 — Example of a scatter diagram

Annex B (informative)
Bibliography

[1] ISO 7870:—[2)], *Control charts — General guide and introduction.*

[2] ISO 8258:1991, *Shewhart control charts.*

[3] ISO 9004:1987, *Quality management and quality system elements — Guidelines.*

[4] ISO 9004-2:1991, *Quality management and quality system elements — Part 2: Guidelines for services.*

[5] IS0 9004-3:1993, *Quality management and quality system elements — Part 3: Guidelines for processed materials.*

[2)] To be published.

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List of references

See national foreword.

BS 7850-2: 1994
ISO 9004-4: 1993

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