

Maintainability of equipment —

Part 6: Guide to statistical methods in maintainability evaluation

Committees responsible for this British Standard

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- AEA Technology
- Association of Consulting Engineers
- Association of Project Managers
- British Gas plc
- British Railways Board
- British Telecommunications plc
- City University
- Civil Aviation Authority
- Consumers' Association
- Cranfield University
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- Royal Statistical Society
- Safety and Reliability Society
- Society of Environmental Engineers
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- West Midlands Enterprise Board

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Contents

	Page
Committees responsible	Inside front cover
National foreword	ii
Introduction	1
1 Scope	1
2 Normative references	1
3 Definitions	1
4 Mathematical back-up material	1
Annex A (informative) Maintainability allocation	3
Annex B (informative) Maintainability demonstration test methods	9
Annex C (informative) Kolmogorov-Smirnov distribution testing	15
Figure A.1 — $\frac{ACMT_{50}}{MACMT} = f \left\{ \frac{ACMT_{95}}{MACMT} \right\}$	7
Figure A.2 — Maintainability allocation to subitem level	8
Figure B.1 — Test method 7: sequential test plan	14
Table A.1 — Maintainability allocation to subitem level	6
Table B.1 — Sampling plans for specified p_0, p_1, α, β ($p_0 < 0,2$)	13
Table B.2 — Test method 7: acceptance and rejection numbers	14
Table C.1 — Critical values of d	15
List of references	Inside back cover

National foreword

This Part of BS 6548 has been prepared by Technical Committee QMS/23. It is identical with IEC 706-6:1994 *Guide on maintainability of equipment — Part 6: Section 9: Statistical methods in maintainability evaluation*, published by the International Electrotechnical Commission (IEC).

Six Parts of this standard have been published and these may be summarized as follows.

Part 1: Guide to specifying and contracting for maintainability. This Part introduces the concept of maintainability and provides guidance on the definition of maintainability requirements and on the programmes needed to achieve them.

Part 2: Guide to maintainability studies during the design phase. This Part provides guidance on studies that should be carried out during the design phase and on the relationship of these studies to maintainability and maintenance support tasks. The purpose of the studies is to assist design decision making, to predict the quantitative maintainability characteristics of an item and to help in the evaluation of alternative design options.

Part 3: Guide to maintainability verification and the collection, analysis and presentation of maintainability data. This Part provides guidance on the various aspects of verification necessary to ensure that specified maintainability requirements have been met and outlines suitable procedures and test methods. Guidance is also given on the collection, analysis and presentation of maintainability data.

Part 4: Guide to the planning of maintenance and maintenance support. This Part provides guidance on the planning of maintenance and maintenance support during the system acquisition phase to ensure that availability objectives are met in the operational phase. The interrelationships with reliability and maintainability programmes are also described.

Part 5: Guide to diagnostic testing. This Part provides guidance on consideration of testability characteristics during the design and development of equipment. It will assist in determining effective test procedures as an integral part of operation and maintenance.

Part 6: Guide to statistical methods in maintainability evaluation. This Part provides guidance on statistical methods for use when allocating maintainability requirements to the various parts of a system, and when carrying out maintainability demonstrations and evaluations.

Guidance on many studies closely related to maintainability is also contained in the various Parts of BS 5760 *Reliability of systems, equipment and components*. Many terms used in this standard are defined in BS 4778 *Quality vocabulary — Section 3.1 Guide to Concepts and related definitions*.

Cross-references

International standard	Corresponding British Standard
IEC 50 (191)	BS 4778 <i>Quality vocabulary</i> Section 3.2:1991 <i>Glossary of international terms</i> (Identical)
ISO 3534-1:1993	BS ISO 3534-1 <i>Statistics — Vocabulary and symbols — Part 1:1993 Probability and general statistical terms</i> (Identical)

Reference to sections of IEC 706

The various Parts of IEC 706 each contain one or more sections. References to these sections are sometimes made in the text. The sections are reproduced in the Parts of BS 6548 as follows.

IEC 706 section number and title	Corresponding Part of BS 6548
Section 1 <i>Introduction to maintainability</i>	BS 6548-1:1984
Section 2 <i>Maintainability requirements in specifications and contracts</i>	BS 6548-1:1984
Section 3 <i>Maintainability programme</i>	BS 6548-1:1984
Section 4 <i>Diagnostic testing</i>	BS 6548-5:1995
Section 5 <i>Maintainability studies during the design phase</i>	BS 6548-2:1992
Section 6 <i>Maintainability verification</i>	BS 6548-3:1992
Section 7 <i>Collection, analysis and presentation of data related to maintainability</i>	BS 6548-3:1992
Section 8 <i>Maintenance and maintenance support planning</i>	BS 6548-4:1993

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 16, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Introduction

Maintainability engineering is the technical discipline directed towards enhancement of the ease of maintenance of equipment. In the preceding parts of this guide, important methods and techniques are presented which can be used to achieve this objective. Many of them are of a qualitative nature; some, however, include also quantitative aspects, especially for:

- allocating maintainability target values to subitems;
- verifying the fulfilment of quantitative maintainability requirements;
- evaluating maintainability data.

For a complete understanding of these methods and techniques, it is necessary to provide some mathematical explanation to enable the user to apply them more generally.

1 Scope

This part of IEC 706 is being issued as section 9 of the guide on maintainability of equipment. It specifies techniques covering some quantitative aspects of maintainability engineering in various phases of the system life cycle.

This part of IEC 706 is applicable to the tasks of maintainability allocation, maintainability demonstration and maintainability data evaluation, as described in sections 5, 6 and 7, respectively, of the guide (IEC 706-2 and IEC 706-3). In the informative Annex A, Annex B and Annex C, mathematical methods and procedures for performing these tasks are presented in corresponding order. The document is intended to serve as an addendum, for specific maintainability topics, to existing statistical textbooks.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 706. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 706 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards. IEC 50(191):1990, *International Electrotechnical Vocabulary (IEV) — Chapter 191: Dependability and quality of service*.

IEC 706-2:1990, *Guide on maintainability of equipment — Part 2: Section 5 — Maintainability studies during the design phase*.

IEC 706-3:1987, *Guide on maintainability of equipment — Part 3: Sections 6 and 7 — Verification and collection, analysis and presentation of data*.

ISO 3534-1:1993, *Statistics — Vocabulary and symbols — Part 1: Probability and general statistical terms*.

3 Definitions

For the purpose of this part of IEC 706, the terms and definitions of IEC 50(191), ISO 3534-1 and of preceding sections apply. Additional terms, symbols and acronyms which are used in some of the annexes are defined in Annex A.

4 Mathematical back-up material

The material under this heading is presented in the order of the related sections of the guide. For each of these sections, the problems to be solved by mathematical means are indicated; the mathematical material itself is then given in an annex.

4.1 Material related to Section 5

Section 5 of the guide on maintainability of equipment deals with maintainability studies in the design phase. One of the tasks considered is the allocation of item maintainability requirements to subitems/lower indenture levels. This is an iterative process starting early in the item life cycle on the basis of preliminary design information, and later on updated when more detailed data and information becomes available. An example of the early type of maintainability allocation is given in Annex A of section 5; the underlying assumption in this case is that the subitem maintainability requirement is inversely proportional to the subitem's complexity.

Annex A presents the method recommended for the updating of the early maintainability allocation. This method should be used when additional design data become available, so that the functional breakdown of the item can be carried down to lower subitem levels, with failure rate values allocated to all subitems. The method is applicable to all systems where the assumption of a log-normal distribution of the corrective maintenance time is satisfied, and where sufficiently detailed design information is available, for example, in or at the end of the definition phase. For application of the method, it needs specification of a maximum allowable time for active corrective maintenance.

4.2 Material related to Section 6

In Appendix A of Section 6 of the guide, statistical test methods are identified, which should be applied to verify the fulfilment of quantitative maintainability requirements. Details of these test methods are described in Annex B. They may be applied to all maintainability demonstrations, when the maintenance events are statistically independent. The test conditions should be representative of the actual conditions of use.

4.3 Material related to Section 7

In Section 7 of the guide, aspects of the analysis of maintainability related data which could be obtained from relevant sources (e.g. historical sources, development or demonstration tests, production, assembly, or field operations), and which should be used for maintainability compliance/determination testing, are briefly described. One important part of this analysis is the determination of the data distribution. In Annex C, the most frequently used method for distribution testing, the Kolmogorov-Smirnov test (also known as *d*-test), is presented. This test is applicable for all types of data and for all distribution forms. For other possible methods (chi-square test, graphical procedures), pertinent statistical textbooks should be consulted.