BS 5760-0:2014

BSI Standards Publication

Reliability of systems, equipment and components –

Part 0: Guide to reliability and maintainability

...making excellence a habit.™

Publishing and copyright information

Published by BSI Standards Limited 2014

ISBN 978 0 580 72465 7

ICS 03.120.01; 21.020; 29.020

The following BSI references relate to the work on this document:
Committee reference DS/1
Draft for comment 13/30232639

Publication history

First published October 1986
Second (current) edition March 2014

Amendments issued since publication

Date	Text affected

Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 26, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 March 2014. It was prepared by Technical Committee DS/1, *Dependability*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This part of BS 5760 supersedes BS 5760-0:1986, which is withdrawn.

Relationship with other publications

The following parts of BS 5760 have been published or are in preparation:

- Part 0: *Guide to reliability and maintainability*;
- Part 2: *Guide to the assessment of reliability*;
- Part 8: *Guide to assessment of reliability of systems containing software*;
- Part 10: *Guide to reliability testing*;
- Part 12: *Guide to the presentation of reliability, maintainability and availability predictions*;
- Part 13: *Guide to reliability test conditions for consumer equipment*;
- Part 18: *Guide to the demonstration of dependability requirements – The dependability case*;
- Part 24: *Guide to the integration of risk techniques in the inspection and testing of complex systems*.

Information about this document

This is a full revision of BS 5760-0 and its changes reflect current practices. While addressing system and equipment level reliability and maintainability, many of the techniques described in the different parts of BS 5760 can also be applied at the component level.

Use of this document

As a guide, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The guidance in this standard is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Introduction

Reliability and maintainability are vital qualities of any system or product. When assessing how good a system or product is, the end user considers four characteristics: how much did it cost, how well does it perform when it is working, how often does it break down and how easy is it to mend when it has broken down. A successful product or system strikes the correct balance between these considerations. This standard provides guidance on how to assess and control the last two considerations, which are formally named reliability and maintainability, respectively.

When a product fails, it as a minimum inconveniences the user as a result of direct costs involved in undertaking repair and loss of use of the product. In the case of systems with a safety implication, unexpected failure can have far more serious consequences. The outcome of failures can range from loss of reputation through direct and indirect financial penalties to legal action. As reliability and maintainability are inherent design characteristics, it is essential that the required characteristics are identified as early in the design process as possible, when the other performance criteria are also being set. If they are not considered at this stage, it is likely that the product will not be satisfactory.

The activities described within this standard normally form part of an organization's asset management strategy and are therefore aligned to, and consistent with, the organizational objectives.

1 Scope

This part of BS 5760 gives guidance on the basic principles of reliability and maintainability that are applicable to any business model.

It is particularly applicable to reliability and maintainability in the design, manufacturing, management and decommissioning of products, equipment, services, plant or structures, and gives guidance on matters of common interest to any business supplying or purchasing products, services, plant or structures.

This part of BS 5760 provides all managers and engineers involved in the specification, design, development, manufacture, acceptance and use of engineering artefacts with guidance on how to manage reliability and maintainability effectively and develop an auditable record of activities. This standard is also applicable to students and anyone else who needs to understand how to develop, manufacture and support systems and equipment that meet the needs of the user by working when required.

This part of BS 5760 does not give guidance on issues relating to safety. However, much of the guidance could also be applied to the production of safety cases.

NOTE Guidance on component reliability is given in BS CECC 00804.

2 Terms and definitions and abbreviations

For the purposes of this part of BS 5760, the following terms and definitions apply.

2.1 active repair time
part of the active maintenance time during which repairs are performed on an item

NOTE This does not take into account any waiting time for maintenance resources.

2.2 availability
ability to be in a state to perform as required

NOTE Availability depends upon the combined characteristics of the reliability, recoverability, and maintainability of the item, and the maintenance support performance.

2.3 intrinsic availability
availability provided by the design, under ideal conditions of operation and maintenance

NOTE 1 Delays associated with maintenance, such as logistic and administrative delays, are excluded.

NOTE 2 Operational availability is determined considering down time due to failures, outages and associated delays, but excluding external causes.

2.4 corrective maintenance
maintenance carried out after fault detection to effect restoration

NOTE Corrective maintenance of software invariably involves some modification.

2.5 dependability
ability to perform as and when required

NOTE 1 Dependability includes availability, reliability, recoverability, maintainability and maintenance support performance, and, in some cases, other characteristics such as durability, safety and security.

NOTE 2 Dependability is used as a collective term for the time-related quality characteristics of an item.

2.6 failure
loss of ability to perform as required, or event that results in a fault state of that item

NOTE 1 Qualifiers such as catastrophic, critical, major, minor, marginal and insignificant may be used to categorize failures according to the severity of consequences; the choice and definitions of severity criteria depend upon the field of application.

NOTE 2 Qualifiers such misuse, mishandling and weakness may be used to categorize failures according to the cause of failure.

2.7 function
activity or feature that an item is required to be capable of doing in order to meet an operational (user) requirement

2.8 integrated logistic support
management process to determine and co-ordinate the provision of all materials and resources required to meet the needs for operation and maintenance

2.9 item
subject being considered

NOTE 1 The item might be an individual part, component, device, functional unit, equipment or system and consist of hardware, software, people or any combination thereof.

NOTE 3 The item is often comprised of elements that may each be individually considered.

2.10 maintainability
ability to be retained in, or restored to a state to perform as required, under given conditions of use and maintenance

NOTE Given conditions include aspects that affect maintainability, such as location of maintenance, accessibility, maintenance procedures and maintenance resources.

2.11 level of maintenance
set of maintenance actions to be carried out at a specified indenture level

[SOURCE: BS 4778-3.2:1991, IEC 60050-191:1991, 191-07-06]

2.12 preventive maintenance
maintenance carried out to mitigate degradation and reduce the probability of failure

2.13 reliability
ability to perform as required, without failure, for a given time interval, under given conditions

NOTE 1 The time interval duration might be expressed in units appropriate to the item concerned, e.g. calendar time, operating cycles, distance run.

NOTE 2 Given conditions include aspects that affect reliability, such as mode of operation, stress levels, environmental conditions and maintenance.

NOTE 3 Reliability may be quantified using appropriate measures.

2.14 reliability centred maintenance (RCM)
systematic method for determining the respective maintenance actions and associated frequencies, based on the probability and consequences of failure

NOTE 1 RCM uses analysis of modes of failure to select the best defence strategy for each possible failure mode.

NOTE 2 RCM studies may be conducted at any indenture level of a system, and provide feedback to initiate modifications of design or procedures to effect improvements.

2.15 reliability growth
iterative process for reliability improvement by addressing design and manufacturing weaknesses

2.16 reliability model
mathematical model used for prediction or estimation of reliability measures

NOTE Modelling techniques may be applied to other characteristics, such as maintainability and availability.

2.17 system
set of inter-related items that collectively fulfil a requirement

NOTE 1 A system is considered to have a defined real or abstract boundary.

NOTE 2 External resources (from outside the system boundary) might be required for the system to operate.

NOTE 3 A system structure might be hierarchical, e.g. system, subsystem, component.

2.18 Abbreviations
For the purposes of this part of BS 5760, the following abbreviations apply.

BIT	Built in test
BITE	Built in test equipment
DRACAS	Data reporting and corrective action system
ESS	Environmental stress screening
FMECA	Failure mode, effects and criticality analysis
ILS	Integrated logistic support
LCC	Life cycle costing
MART	Mean active repair time
MTBF	Mean time between failures of the system
R&M Case	Reliability and maintainability case
RCM	Reliability centred maintenance
MTTR	Mean time to repair
WLC	Whole life cost

3 Basic principles of reliability

3.1 General

Reliability is used to measure how likely items are to function to fulfil their designed specification, when required. The observable result of reliability can be viewed from two perspectives. The first is the ability to deliver its design performance and functionality on demand during a defined operational period. This is normally expressed as a probability. As a probability, reliability is strictly a number between 0 and 1, often quoted as a percentage.

The second is the necessity of undertaking repairs when the system fails or becomes defective in some way. This is typically expressed in the form of the failure rate, or mean time between failures. In both cases, the reliability is exactly the same, but the first perspective is of primary interest to the user of the item and the second to those who maintain it. The elements which affect reliability are given in **3.2** to **3.6**.

3.2 Required function

During concept studies of new items (**6.3.1**), the functions that are required to enable it to complete its task successfully should be identified and an analysis should be performed to define the capabilities and performance requirements of the item.

In items that are capable of many functions, some of which might not be continuously required, the importance of each function should also be identified.

NOTE It is often the case that some functions are regarded as critical to task success, whereas others might simply be desirable.

3.3 Failure

Reliability cannot be measured directly for a single item in the same way as weight, speed or most other performance measures. This is because reliability is a stochastic [1)] parameter that is dependent on unpredictably occurring events, i.e. failures.

Reliability should only be measured to a level of statistical confidence for a number of items, or the operation of one item over many instances. The level of confidence in the item should increase with the amount of data that is available but it is never likely to reach 100%.

The meaning of failure should be defined because its meaning is dependent upon the item requirements. Initial definitions of failure should be taken into account during the analysis of performance requirements when they would be categorized as critical or non-critical. The latter should be termed a fault or defect.

*NOTE 1 A defect is an incident that might or might not degrade equipment performance but does require corrective maintenance (**6.4.5.2**).*

Failure definitions should be established early and be included in the reliability and maintainability requirement specifications. They should be clear, concentrate on objective criteria and be based on effects rather than on causes.

NOTE 2 Further information on failure patterns is given in Annex A.

3.4 Performance

The performance represents the limiting boundaries of the functionality of an item. For example:

a) maximum forward or reverse speed;

b) maximum rate of turn; or

c) minimum number of communication channels available.

The type of parameter to be considered depends upon the specific item and its intended use.

1) Having an element of chance (as opposed to deterministic parameters, which can be measured repeatedly).

3.5 Conditions

The environmental conditions (temperature, pressure, chemical, dust, etc.) in which an item is used, stored and transported, and the way in which it is operated and maintained, can have a major influence on its reliability. These conditions should be defined to the design team during the design and development of an item.

NOTE For example, a standard car could not be expected to achieve the same reliability when driven on desert tracks as it would in UK road use; cars intended for such use are especially designed for the conditions.

3.6 Usage times

The period of usage in which an item is expected to function should be determined as part of the development of requirements (**5.2**).

NOTE For example, the typical flight pattern for an aircraft, a typical day for a transport vehicle, the period between major shut downs for an industrial plant, or a 12 month period for an eCommerce system.

Reliability of items might vary with their age (covering calendar time, usage time, distance travelled, number of cycles or whatever metric is appropriate). Separate requirements for reliability under different conditions or for different periods of time (for instance summer or winter use, or periods of continuous use versus intermittent usage) should be identified and related to the relevant functions.

4 Basic principles of maintainability

4.1 General

Maintainability is the quantitative assessment of how easily and quickly preventive maintenance might be performed or a system restored to functionality through corrective maintenance (**6.4.5.2**). This is dependent upon both the environment in which maintenance is performed and the resources available to do so.

The considerations associated with maintainability are given in **4.2** and **4.3**.

4.2 Maintenance context

These are the conditions under which preventive maintenance or repair is conducted. Factors such as ease of access, maximum allowable downtime, temperature, field or workshop conditions, and lighting and restrictive clothing should all be defined to the design team if they are externally imposed, or should be taken into account by the designers in response to the overall reliability and maintainability requirements if not.

4.3 Stated procedures and resources

The customer or user might put constraints on the resources allowed for preventive maintenance and repair.

NOTE For instance, where items need to fit into an existing maintenance environment, e.g. an aircraft.

These could include skill levels and number of maintainers, storage capacity for spares, tools or handbooks, special-to-type tools or test equipment and availability of utilities. Although influenced by these factors, the designers should be responsible for defining procedures for preventive maintenance and repair as they evolve from the design.

5 Managing reliability and maintainability

5.1 Managing reliability

In order to achieve consistent reliability, management should take action to demonstrate that reliability is important to the company by exhibiting a high level of commitment to see that all the necessary actions specified in the concept stage (**6.3**) are undertaken.

The following principles should be taken into account when managing reliability:

a) reliability personnel should form an integral component of the design, production and sales/marketing operations of a company but have their own chain of responsibility, ending at Board level (i.e. a reliability and quality director);

NOTE 1 This is to make it possible for junior reliability and quality personnel to appeal for judgement over the heads of those they advise, to provide a ladder of advancement within reliability and quality, and to emphasize that reliability and quality are just as important as any other principal functions in a company.

b) reliability and quality are everybody's business and responsibility; motivational mechanisms such as reliability and quality participative groups should be set up and the benefits (improved profits, etc.) shared with the workforce;

c) formal rules that recognize the potential contribution of reliability in the design function should be implemented;

NOTE 2 These rules recognize the need to learn from the experience of users and to be constantly improving reliability to keep up with competitors. The principal techniques are design review programmes involving successive analyses (e.g. failure mode effect and criticality analyses) before a design is marketed, and audited on the basis of operational experience to point the way to improvements in the next design.

d) performance data should be provided by the system user to the producer or obtained by the producer from the user to ensure that failure data is beneficial to both parties;

e) there should be a company reliability and quality manual (usually one single document) serving the following purposes:

   1) documentation of procedures, standards and personal responsibilities for reliability and quality (subject to regular review and amendment); and

   2) demonstration to both employees and customers that the management is committed to raise levels of reliability and quality and maintain them for mutual benefit.

Company directors should realize that reliability is an investment, not an expense, and should take an entrepreneurial attitude to it. Reliability, which is a vital but often forgotten part of quality, should commence as early as the concept stage (**6.3**) and continue right through to the operation and maintenance stage (**6.6**).

Reliability technology makes full use of feedback of operational performance wherever possible. Reliability should be determined early in the design and development stage (**6.4**).

NOTE 3 The more firm the design, the more expensive it becomes to make changes. During design, only the designer's time is required to make modification; at the prototype stage, components have to be both re-designed and re-made, from which it is a short step to the recall of thousands of finished products.

5.2 Developing the requirements

At the concept stage of a new item, the required reliability and maintainability characteristics should be prioritized. The challenge of meeting these requirements should be assessed and an appropriate programme of activities put in place in order to ensure that the requirements are met in an effective manner. When identifying the required reliability and maintainability characteristics, the following should be taken into account:

a) the customer's or user's perception of reliability and maintainability characteristics; and

b) the customer's or user's expectations (**5.3**).

During the development of an item, reliability and maintainability characteristics should be cascaded from the overall item down to sub-assemblies. All cascaded requirements should be coherent and result in an item that meets the overall requirement.

Understanding how the item is used should be an integral component of identifying the requirements, as relatively small changes in usage might have a major impact on the overall reliability and maintainability characteristics perceived by the user.

5.3 Managing expectations

When deliberating between competing products or services, potential customers consider various factors before coming to a decision. These factors include price and timeliness of delivery, and also inbuilt design-related attributes such as functionality and usability. Customers might take into account other factors, such as whether it will work the first time, whether it works every time, and whether any problems are simple to resolve.

NOTE Depending on the value of the potential investment and the awareness of the customer, these latter items might be considered explicitly through detailed analysis, or implicitly through examination of the vendor's reputation for delivering reliable and maintainable products. As with all aspects of reputation management, damage caused by the delivery of unreliable products or services can take years to repair.

5.4 Financial impact

Reliability and maintainability are characteristics similar to functionality and usability in that they are inherent in the design and difficult and costly to change once the design has been finalized. Given their impact on the financial success of a product or service, they should be managed as proactively and closely as the functionality of a product or a service.

NOTE Provided that sufficient customers select the relevant product or service, the first measure of success from the producer's viewpoint is whether it can be produced at an appropriate cost. Additional success factors depend on the reliability and maintainability of the offering, as these often have an immediate financial impact in the value of warranty claims and the amount of repeat business that is generated.

6 Availability, reliability and maintainability in the life cycle

6.1 General

Availability, reliability and maintainability are aspects of the functionality required of an item to enable it to successfully undertake the task or mission for which it is designed and manufactured. Therefore, all three should be taken into account from the concept studies (**6.3.1**).

6.2 Project life cycle

Individual projects have their own specific life cycles. Each project life cycle should encompass the reliability and maintainability activities illustrated in Figure 1. These activities should aim to:

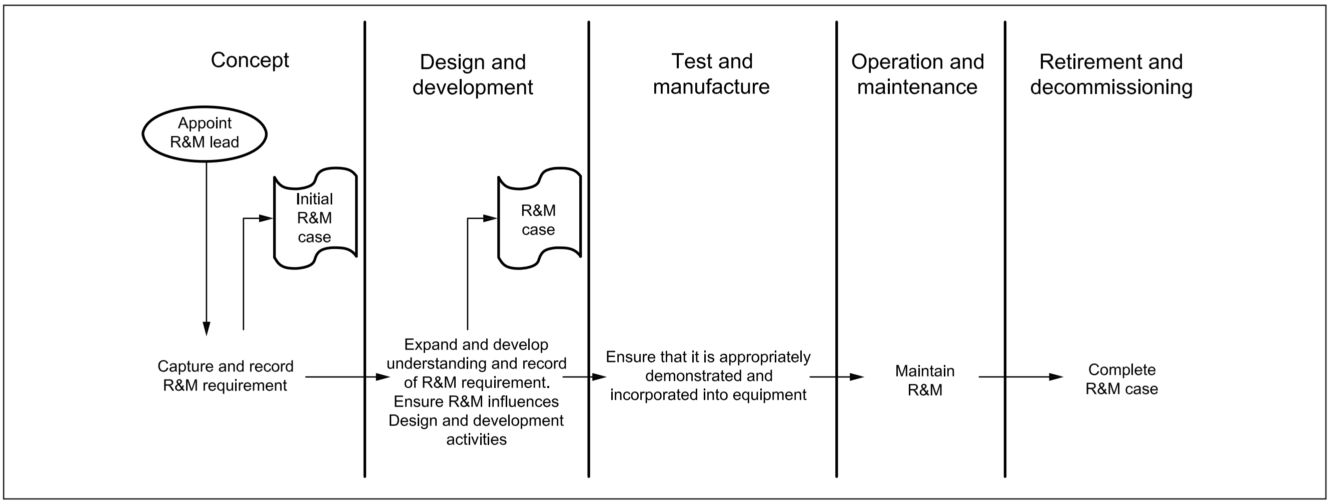
a) define the reliability and maintainability requirements;

b) expand and develop understanding of the requirements and plan contingencies for risks;

c) implement and review the reliability and maintainability programme; and

d) monitor reliability and maintainability performance in service.

Figure 1 **Project life cycle**



6.3 Concept stage

6.3.1 Concept studies

The depth and scope of concept studies should correlate to the capability required from the item under consideration.

NOTE For example, a straightforward requirement for replacement of an existing item might lead to studies of what is available on the market, whereas a requirement for an entirely new application or environment often requires a more detailed approach.

The identified approaches and trade-offs required to support concept development should be initiated or taken into account during concept studies. In order to achieve this, an analysis of requirements should first be performed. This provides the functionality against which initial studies of performance, availability, safety, support and cost can be undertaken.

6.3.2 Initial activities

The analysis of requirements should provide information from which initial reliability and maintainability targets can be derived. At this stage a group of reliability and maintainability stakeholders should be established whose role is to:

a) sponsor the concept studies;

b) ensure that targets are realistic and achievable; and

c) establish and endorse the failure definitions (**3.3**) that are an outcome of the requirements analysis.

The following reliability and maintainability activities should also be undertaken at this stage:

1. the initiation of a reliability and maintainability case (**6.3.3**), which should provide progressive assurance that not only are the reliability and maintainability targets realistic and achievable, but that at each stage of the cycle all work necessary for achievement has been completed. This includes a full record of all assumptions, data sources and calculations to support and justify reliability and maintainability requirements; and
2. the initial identification of reliability and maintainability risk areas for inclusion in the project risk management plan and to guide work in the design and development stage.

During the early stages of a project the following should be taken into account:

i. reliability and maintainability requirements are justified against operational needs, as well as technically and economically achievable; and

ii. failure definition and any environmental and operating conditions that are integral parts of the reliability and maintainability requirements.

6.3.3 R&M Case

The R&M Case provides an audit trail of the engineering considerations from requirements (**5.2**) through to evidence of compliance. It provides the traceability of why certain activities have been undertaken and how they can be judged as successful. The R&M Case should be initiated at the concept stage (**6.3**) and summarized in reports at predefined milestones.

NOTE 1 As the acquisition or development progresses, the analyses, strategies, plans, evidence, assumptions, arguments and claims provide a progressive assurance.

The R&M Case should focus on progressive assurance so that less reliance is placed on reliability and maintainability demonstrations of the final design.

NOTE 2 A complete description of the process is given in BS 5760-18.

6.4 Design and development

6.4.1 General

This stage represents the greatest opportunity for influencing the reliability and maintainability characteristics of an item. The main actions initiated in this stage are:

a) a reliability and maintainability programme for the remaining stages;

b) development of an availability model in line with the evolving design, which is used to support trade-off studies; and

c) reliability and maintainability risk assessments undertaken at a level of detail in line with the evolving design.

Typically a high level FMECA is developed to assist in evaluating the reliability characteristics of the item and to form the basis for identifying maintenance activities. Outputs of the these activities should be used to:

1. determine optimum support policies; this might be in the form of an ILS approach, if required;
2. turn the reliability and maintainability targets into firm requirements for inclusion in the requirements document and in contractual specifications; and
3. provide input into LCC calculations (**8.5**).

Stakeholders and members of the project team should optimize the eventual operational availability by ensuring the timely establishment of adequate support arrangements to cover the needs of the system for spares and repairs.

6.4.2 Designing for reliability

At this stage preliminary and baseline designs should be produced. In assessing these it should be recognized that the principles of designing for high reliability are the same whatever the technology. The following principles should be taken into account:

a) evaluate reliability of the design from the start;

b) ensure that the correct environment is considered;

c) where possible, use proven components and exclude known problem areas;

d) design to be durable;

e) minimize the number of components;

f) reduce stress on components and allow adequate safety margins;

g) design for manufacture; and

h) allow for parameter variations (tolerances, ageing and drift).

In order to increase reliability, a conservative design approach should be evaluated. In doing so, it might be necessary for some aspects of performance to be reduced, for example lower speed or increased weight. This illustrates the importance of trade-off as part of concept studies (**6.3.1**) early in the life of a design, where the impacts of the competing pressures of performance, reliability, cost and delivery are assessed to achieve an optimum balance.

NOTE 1 This does not mean that high reliability precludes technological advances, but the use of novel technology might require additional reliability testing or the application of new techniques.

NOTE 2 Technical progress is usually by incremental advances and the reliability of forerunner equipment is well known because of the large number in use. The wider benefits of incremental progression are now recognized and these are equally applicable to the achievement of high reliability.

6.4.3 Reliability analysis

To determine whether a design has the potential to satisfy the reliability requirement, a reliability model should be used in the analysis process. Reliability data is often imprecise due to the inaccessibility or inaccuracy of historical information, and data gathered for a particular system or equipment might not be directly applicable to other cases.

NOTE 1 For example, where the environment, manufacturing quality, failure definition or some other factor or combination of factors differ.

This potential inaccuracy should be recognized and allowed for in analyzing reliability. Unless novel or unconventional technology is being considered from the start, the top-level systems and sub-systems should be based on appropriate (preferably in-service) equipment for which data is available. Even in the case of novel technology the reliability and maintainability capability of conventional equipment should be analyzed in the same role to provide a baseline reference figure. Data can be obtained from a variety of sources; the following should be used if available and are given in order of preference:

a) the same or similar equipment used by the purchaser in the same operational, physical and support environment;

b) the same or similar equipment used by other users in a similar physical environment, for example, commercial aircraft data for business jet applications;

NOTE 2 In this case it is unlikely that the operational and support environments are the same and appropriate allowances might have to be made before the data is used.

c) data derived from a detailed physical and engineering analysis of the short and long-term behaviour of the system or equipment proposed across the range of environmental conditions in which it is used; and

d) generic data.

If data of the quality of a) or b) is not available, an internal data gathering exercise should be set up to provide results during the concept stage or during assessment. Data from c) is unlikely to be available at the outset. Generic data should be used with great caution and can lower confidence in the modelling results until it can be replaced with more reliable data.

In addition to reliability modelling, the following techniques should be used in the design to concentrate on areas that are critical to system reliability:

- reliability design checklists;
- allocation/apportionment of reliability targets from high level to lower levels or between major items of the system;
- FMECA; and
- reliability design reviews.

Reliability of functions identified as critical are improved by:

- redesign for improved component reliability (i.e. decrease the stresses acting on the component); and
- redesign fault tolerances to remove critical single point failures (i.e. introduce redundancy or diversity).

During assessment the analyses should be progressively refined to reflect the design in sufficient detail and to inform and positively influence design decisions.

In undertaking reliability assessments, factors other than the system components should also be examined. The following could all have a crucial impact on the reliability of the system in operation:

- system integration;
- human interaction;
- software; and
- the effect of the environment.

6.4.4 Designing for maintainability

The following should be taken into account when designing for maintainability:

a) maintainability of the design should be evaluated from the start;

b) failures should be readily detected and easily diagnosed when they occur;

c) the design should, as far as possible, be modular;

d) modules should be easily accessible, especially where frequent access is required (for maintenance, replenishment, or replacement of high failure rate items, etc.);

e) there should be no need to remove a functioning unit to gain access to a failed one;

f) special tools should be kept to a minimum;

g) the need for adjustments and calibrations should be minimized;

h) special test equipment should be designed together with the item itself; and

i) attention should be given to design detail such as labelling, keyed connectors to prevent cross-connection, captive fasteners, test points, content indicators, provision of handling points, and suitable connectors where frequent disconnection is required.

During this stage maintainability activities are concerned with ensuring that the right influence is introduced during the developing design. Design criteria, derived from a) to i) should be listed and applied.

6.4.5 Maintainability analysis

6.4.5.1 Preventive maintenance

Planning for preventive maintenance should be undertaken in a systematic way so that the tasks and methods used are clear and practicable. The RCM approach (**2.14**) should be used to select the best preventive maintenance strategy for the specific conditions in which an item is intended to function. This approach examines individual failure modes and provides a means to choose between preventive maintenance on a time basis or on a condition basis, or to have repair on failure only.

NOTE 1 The RCM method provides an audit trail of why specific preventive maintenance tasks and schedules have been selected.

NOTE 2 Techniques other than RCM exist for assessing preventive maintenance needs but it is now widely used and builds on standard reliability analysis tools and techniques.

Systematic development of preventive maintenance tasks should be conducted for new items, and retrospectively for existing ones. The planned maintenance scheme should be consistent with the constraints on downtime, frequency and manpower which were defined as part of the specification of requirements (**5.2**).

6.4.5.2 Corrective maintenance

The repair time for each of the repair (corrective maintenance) actions on an item can differ. Therefore the distribution of repair times for the item as a whole depends on how often each of the repair actions is required and the time for that action. In order to predict mean repair times for an item, the failure rate leading to each repair action and the amount of time required for each active repair (i.e. isolation, disassembly, etc.) should be identified.

FMECA should be used to provide major data input to a mean repair time prediction.

NOTE FMECA analyzes how and how often each part of a system might fail. This analysis can be expanded to show how the failure would be detected (i.e. its symptoms) and how it is corrected.

The repair time prediction estimates the times for each part of the corrective action and the overall distribution of repair times.

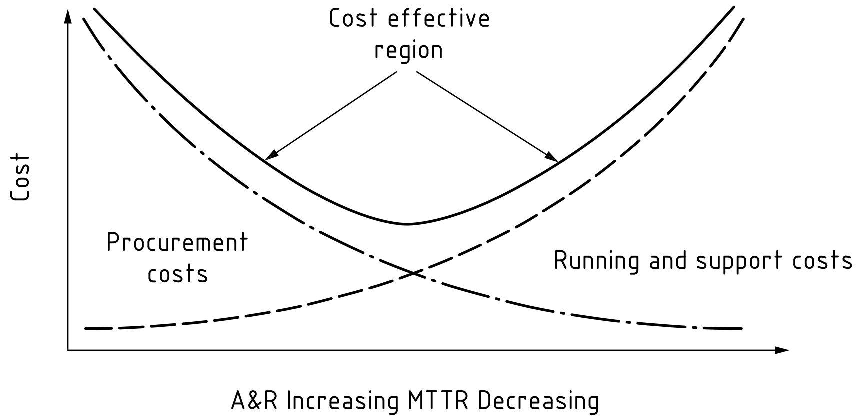
6.4.6 Improving intrinsic availability

In some applications the availability of an item should be taken into account as well as the reliability or maintainability in their own right (see Annex B).

NOTE Satisfactory availability might be achieved on low reliability equipment if the repair times are very short (e.g. simple software reboot). However, achieving the required level of availability with frequent interruptions might not be satisfactory because of the effects on support costs or perception of equipment quality.

Balancing reliability against maintainability should be the subject of studies conducted early in the assessment of a design in conjunction with initial spares ranging and scaling, and life cycle cost studies. This permits an optimum balance between procurement and running costs to be achieved while ensuring that operational requirements are met, see Figure 2.

Figure 2 **Achieving high availability**



6.5 Test and manufacture

6.5.1 General

During the testing stage development risk should be progressively eliminated, and evidence that reliability and maintainability requirements are achievable and being met should be accumulated. This is achieved by using the R&M Case (**6.3.3**) and risk management plan.

At the manufacturing stage the R&M Case should be brought up to a standard suitable for handover to those responsible for operating the equipment in service, and should be offered as evidence of reliability and maintainability achievement. Any reliability and maintainability modelling should also be handed over as it can be used to assist management decision making as an accurate representation of the reliability and maintainability of the system.

6.5.2 Realizing potential reliability

Once examples of the item (or parts of it) are produced, they should be tested to provide actual information on reliability as well as performance.

NOTE 1 Development testing aids reliability growth by finding and removing shortcomings from the design.

Testing should reveal any systematic problems with the current design and once known, cures for each problem should be devised and reliability improved.

To produce reliability growth, information on systematic problems and failures are helpful. To induce them to happen more frequently, the item should be overstressed by testing in a harsher environment. If this route is taken it should be ensured that the harsher environment does not, of itself, cause different failure modes to occur.

Information from any reliability and maintainability events arising, no matter where in the development programme, should be gathered, analyzed and acted on promptly. For this reason a closed loop DRACAS should be established to cover all discrepancies and failures that happen during design, testing and manufacture.

NOTE 2 A DRACAS is one of the reliability and maintainability engineer's most powerful aids, from the commencement of detailed design through to and including production.

6.5.3 Maintainability testing

Maintainability testing is used in place of, or to support, repair time predictions. It should consist of undertaking a number of typical repair actions, with the sample faults being carefully selected to provide a broad distribution of repair times and frequency, and measuring the time taken for each. The measured distribution should then be compared with accept/reject criteria derived from the requirement specification (**5.2**).

The following should be taken into account during maintainability testing:

a) the test should be on a sample of the fixed final build standard;

b) the test should apply to the same level of maintenance (**2.10**) as the repair times set out in the requirements (e.g. first line) and should therefore use the same repair philosophy;

   NOTE If first line repair action is to exchange a whole module and send it back to workshops for internal repair, it is the module exchange time rather than the internal repair time which is recorded.

c) test conditions should be representative (i.e. accessibility, tools, handbooks, etc.);

d) repairs should be conducted by a variety of repairers, representative in skills, training and experience of those who would do the actual repair in service (ideally service staff who have undergone a training course on the system);

e) repair actions should be on a mixture of failures representative of the proportion expected to occur in service;

f) the test maintainers should have no advance knowledge of the repair they are required to undertake; and

g) all failures should be introduced in a safe manner.

6.5.4 Operational availability

As well as the continuing work on reliability and maintainability, the main benefits to operational availability should be achieved by refinement of spares ranging and scaling, and the establishment of support facilities (i.e. workshop or logistic support infrastructure).

6.5.5 Manufacture

The reliability and maintainability activities during manufacture are concerned with ensuring that the design's reliability and maintainability potential is not compromised by production methods. The manufacturer should screen out weak components and manufacturing defects to prevent early life failures reducing the item reliability. DRACAS (**6.5.2**) should be continued throughout production.

NOTE 1 It is possible to conduct sampling tests to detect a fall in production reliability, although this is not often practicable.

NOTE 2 Reliability testing of the finished product to detect any fall-off in production is not possible where the item is complex and expensive, the required reliability is very high or the production run is small.

ESS (or burn-in testing) is an acceptable and frequently used technique, but it should be planned and not conducted in a haphazard way. Plans should be developed and improved in the light of experience. There should be no penalty for failures during environmental stress screening since these benefit the user. However, environmental stress screening failures should be subject to DRACAS.

In the absence of an adequate quantitative reliability test or DRACAS data, an in-service reliability demonstration should be undertaken on an early delivered item.

NOTE 3 This can determine that the actual reliability in the operational environment meets requirements before final acceptance or acceptance into service.

Alternatively, a controlled in-service reliability and maintainability data gathering trial should provide hard evidence of reliability and maintainability performance and provide data adequate for acceptance into service.

6.6 Operation and maintenance

During the operation and maintenance stage the organization should concentrate on monitoring and sustaining, or improving the initial levels of reliability and maintainability throughout the item's life in service and continuing the R&M Case (**6.3.3**). When the item enters service, reliability activities should be focussed on maintaining the level of reliability and influencing any redesign or modification activities to ensure good reliability practice.

Preventive maintenance tasks (**6.4.5.1**) should be undertaken to ensure that component parts of the item do not reach the wear-out region of their failure curve, where this is applicable (see Annex A). The majority of preventive maintenance tasks should be undertaken as scheduled maintenance.

Information on failures in the service environment should be fed through the DRACAS to support design changes and future purchases for improved reliability.

NOTE 1 The actual service environment might be different from the test environment and can therefore give rise to different failures.

Reliability and maintainability data from field usage should be used to provide:

1. feedback to designers to identify and solve reliability and maintainability problems;
2. data for claiming against the supplier's warranty; and
3. feedback to keep the availability model up to date and support management decisions in areas such as spares holdings, and for setting targets for future equipment.

Modification analysis should be undertaken to examine the effects of proposed modifications on reliability and maintainability performance, and to confirm that there are no detrimental effects before the modification is approved.

When monitoring reliability and maintainability performance during the operation and maintenance stage, the following should be taken into account:

a) operational reliability and maintainability performance can be very different to reliability and maintainability predictions, simulations and even testing;

b) because operational performance is what really matters to the user, the equipment should meet its reliability and maintainability requirements in service before contract acceptance where appropriate;

c) the measurement of reliability requires that usage should be known (and recorded) as well as the number of defects/failures;

NOTE 2 An operational reliability demonstration can impose a significant data recording burden on the user. A controlled operational trial might be less onerous.

NOTE 3 Reliability and maintainability problems with operational equipment (both low and high technology) are often the result of cumulative minor problems.

d) design changes for operational equipment can improve reliability but are more expensive than those introduced at the original design stage; and

e) equipment redesign for modifications during operation requires the same specification and assessment techniques as during original development to ensure that acceptable reliability and maintainability characteristics are achieved.

6.7 Retirement and decommissioning

By this time the organization has invested significant resources over many years, the results of which reside in the R&M Case. This is now a valuable source of information for future reference and should be fed back into the concept stages of succeeding systems.

The R&M Case should therefore be catalogued, cross-referenced and archived by a specialist reliability group if necessary.

7 Use of reliability and maintainability in tenders and contracts

7.1 Reliability and maintainability in procurement specifications

The description of reliability and maintainability activities during the concept stage (**6.3**) indicates that the first steps are to investigate what levels of reliability and maintainability are operationally necessary, to identify initial reliability and maintainability risks, and then to see whether the required levels are realistically achievable. The following should therefore be taken into account when producing any reliability and maintainability specification:

a) an investigation or analysis to determine the functionality and provide initial indications of the level of reliability and maintainability should be undertaken; or

b) operational data from similar equipment the likely reliability and maintainability achievement obtainable should be identified.

The content of a reliability and maintainability specification is dependent on the stage of procurement and the amount of reliability and maintainability work undertaken previously, and it should include the following activities:

1. a detailed reliability and maintainability programme for the stage and a plan for subsequent work;
2. clear and unequivocal output from the various reliability and maintainability activities comprising the stage; and
3. progressive assurance and input to the R&M Case.

The specification should also include the following technical elements:

i. reliability and maintainability requirements that are realistic and attainable and reflect what is required, not what might be desirable;

ii. a clear and precise failure definition (or definitions for different classes of failure);

NOTE 1 The reliability requirement has no meaning without an explicit definition of failure.

iii. the environmental and operating conditions are a fundamental part of the reliability and maintainability requirements and should therefore be taken into account when arriving at the failure definition(s); and

iv. minimum levels of reliability, maintainability and availability should be specified in a way that leaves some freedom for the designer to balance between them and performance.

The reliability and maintainability requirements should be such that their achievement is demonstrable through the R&M Case (including trials and analysis as appropriate).

When specifying reliability and maintainability requirements in a tender, care should be taken to balance the probable cost of the programme against the level of reliability and maintainability needed to achieve the requirement.

NOTE 2 This might result in the need to undertake trade-off studies. In addition, if reliability and maintainability requirements are set higher than can possibly be achieved, a bidding contractor might still accept them through ignorance or the desire to win the contract at all costs.

7.2 Contracting for reliability and maintainability

Where reliability and maintainability requirements form part of a written agreement, the following points should be taken into account:

a) there is a reasonable transfer of reliability and maintainability risk from the purchaser to the supplier;

b) milestone payments are linked to specific achievements, such as successful completion and acceptance of the reliability and maintainability case report rather than the passage of time or progress of work irrespective of results;

c) the reliability and maintainability plan should form part of the written agreement and might be called up as a separately identifiable document;

d) a binding and realistic failure definition and assumptions are vital; and

e) the commitment to reliability and maintainability should be translated into a clear obligation.

NOTE The use of financial penalties within written agreements can provide a means for which contractor focus on provision of good reliability and maintainability can be achieved.

7.3 Reviewing a tender for reliability and maintainability

When selecting a contractor for a project, the company's proven ability to produce equipment with good reliability and maintainability characteristics is an important selection criterion. When reviewing a tender, the following points should be taken into account:

a) for new developments, the marking scheme should concentrate on reliability and maintainability experience, understanding and commitment;

b) claimed numerical values of reliability and maintainability should be backed up with a clear explanation of how they were derived;

c) if based on prediction alone the marking should be conservative;

d) for off-the-shelf procurements, the marking scheme should concentrate on credible evidence of reliability and maintainability performance in similar conditions and on commitment to production related reliability and maintainability activities;

e) the tender should evidence experience of reliability and maintainability activities and a good track record of delivering reliability and maintainability performance;

f) the tender should demonstrate that reliability and maintainability activities are conducted to benefit the design, not as an independent activity to document it; and

g) the tender should unequivocally accept the reliability and maintainability requirements.

7.4 Maintainability requirements in tenders and contracts

When specifying or evaluating the maintainability achievable by a design, it should be recognized that some operational factors are beyond the control of the designer, such as waiting time for spares or maintainers and the level of training of maintainers. However, the designer should take account of such factors and produce a design in which any failed item can be rapidly identified and repair or replacement quickly and easily performed. This is particularly important if only low skilled personnel are available, and the designer should produce a design requiring the least practicable preventive maintenance.

NOTE For these reasons, maintainability is specified in terms of "active" repair times. These are the times that it would take a trained maintainer, with repair manuals, adequate spares and test equipment to locate a failure, repair it and restore the item to a fully functioning state.

Measures should be taken to quantify or specify the maintainability characteristics of an item. The following parameters should be used to measure maintainability:

a) mean active repair time (MART), i.e. the total active time (T_N) taken to carry out a large number of repairs (N) divided by N;

b) mean time to repair (MTTR); similar to MART but this expression is used with active or standby redundancy where there is no requirement to commence a repair immediately in order to restore the system to operation, and includes waiting time for resources; and

c) maximum time to repair (or 90th or 95th percentile); for complex systems or equipment it is difficult to specify how long the most time consuming repair should take, therefore a time is specified within which 90th or 95th per cent of all possible repairs can be carried out.

If two of these parameters are specified, the designer should be able to introduce an adequate design and sufficient features to meet the requirement. However, requirements should not impose unreasonable targets (that is, unrealistic for the type of technology under consideration) as this drives up costs and timescales during development and production and might prove to be ultimately unachievable.

8 Interaction with related disciplines

8.1 General

There are a number of engineering disciplines that add value to a design and should be taken into account when developing a reliability and maintainability programme. Recommendations on the disciplines that are likely to be relevant to the majority of items are given in **8.2** and **8.3**.

NOTE Annex C gives information on ILS, which addresses the management of in-service reliability and maintainability in major projects as part of the design process.

8.2 Dependability

Dependability has a strong impact on the user's perception of the value of an item developed or provided by an organization.

NOTE 1 Poor dependability affects the perception of the organization's capability and reputation to deliver its objectives. In this respect, dependability describes the extent to which something can be trusted to behave as expected. Reliability and maintainability characteristics form a substantial part of dependability assessment.

Many of the wider aspects of dependability should be applied to reliability and maintainability activities in order to add value and aid the management and control of projects.

NOTE 2 The management of dependability is a systematic approach for addressing dependability and related issues from an organizational and business perspective and is fully discussed together with applicable techniques in BS EN 60300 (all parts).

NOTE 3 The dependability case (see BS 5760-18) was developed from reliability and maintainability practices and can therefore be applied to considerable effect in managing a reliability and maintainability programme.

8.3 Safety

Safety, together with reliability and maintainability, is an inherent design characteristic of equipment and analyses should be conducted early and in parallel with reliability and maintainability activities to benefit the design.

Demonstration that the design is likely to satisfy the required level of safety is achieved through reasoned engineering assessment.

NOTE 1 Absolute safety (like total reliability) can never be assured. Even where specific levels of safety are required it is unlikely to prove by testing that they have been achieved. This is analogous to reliability assurance, when the required level is high and demonstration testing is not always practicable in a realistic time.

The following four questions should be asked when conducting safety analysis:

- What can go wrong?
- When or how often is it likely to happen?
- What are the consequences?
- Is the result acceptable or unacceptable?

As with reliability, the theoretical assessment of a design should be complemented by feedback from real operational use. Usage data should be collected as well as the recording of accidents and near misses. The in-service data recording should be integrated with data recording for reliability and maintainability purposes.

NOTE 2 In a similar manner to reliability, modification of the design or a change of application can lead to safety problems. The addition of safety features to a system can tend to decrease the reliability because the larger number of parts means that there is more to go wrong. This is also true where BIT, BITE and protective devices are provided to stop the system working in abnormal conditions.

Where a balance between safety and reliability is required, safety should always take precedent.

8.4 Human factors

Techniques for assessing human factors should be used in reliability and maintainability engineering to reduce the number and seriousness of system failures and to improve maintainability.

NOTE 1 Human factors are inter-related with reliability and maintainability as a discipline because humans form part of every engineered system, in the design, manufacture, maintenance and almost always, the operation. It can be said that every failure of a system has a human related root cause, be it operation, maintenance, manufacture, design or specification.

The contribution of human-induced errors should be identified when the designer and reliability and maintainability engineer are allocating the reliability and maintainability requirements to different parts of the system. The following should be taken into account:

a) degradation of human performance (e.g. under physical or psychological stress);

b) human performance limitations and variability;

c) suitable maintenance environment (accessibility, space, etc.);

d) location and design of controls and displays;

e) need for/design of operating and maintenance procedures;

f) skill level and training of operators and maintainers; and

g) credible human errors of omission, commission or substitution.

There should be a two-pronged approach to human induced error:

a) minimize the occurrence of human error (through interface design, environment, training, arousal level, etc.); and

b) reduce the consequences of error (make errors reversible, provide protection, monitoring or warning systems).

The DRACAS (**6.5.2**) should also include all problems with the system that relate to human error. Therefore, two adjacent power supplies that have been cross-connected or a shortcoming in the operating or maintenance manuals should be included in the DRACAS so that corrective action can be taken.

Defects or failures occurring during tests or in service should be analyzed to detect whether human causes were involved.

NOTE 2 These can be valid failures counting against those allowed in a reliability demonstration test, if they were due to designers not considering credible human errors or demanding excessive human performance.

8.5 Life cycle cost

The reliability and maintainability of an item has significant impact on its LCC. The evaluation of LCC or WLC should therefore form part of a reliability and maintainability programme. Where this is the case, the costs associated with the support activities which arise as a direct result of the reliability and maintainability characteristics should be evaluated, for example, maintenance staff, spares, tools, etc. These costs should be used to direct reliability and maintainability design activities where they form part of the trade-off with the other major LCC contributors, including:

a) running costs (i.e. cost of operators, consumables such as fuel, oil, tyre, etc.); and

b) replacement costs (i.e. depreciation, disposal etc.).

The lowest purchase price does not guarantee the lowest WLC, therefore reduction in reliability and maintainability performance should not be used to minimize purchase price without due consideration of their LCC impact.

NOTE 1 In a large number of cases a higher capital cost (development and production) means a lower WLC of ownership. As an acquisition cost, expenditure on achieving reliability and maintainability might be thought to increase LCC. However, when reliability and maintainability engineering positively influences the design from the outset and continues to eradicate problems by analysis and testing throughout development, the payback over the life of the equipment is many times the additional cost to the acquisition process. Over a long operational life, increased reliability and a lower maintainability figure often results in fewer spares and maintainers required. Better preventive maintenance improves reliability and availability.

The LCC should be as low as possible given that specified characteristics and performance are satisfied. Because reliability and maintainability are major cost drivers of LCC, they should be included in the specified characteristics.

*NOTE 2 In some large organizations, especially government or military ones, acquisition costs and in-service costs are paid from different budgets. It is now generally recognized that increased acquisition costs up front can frequently lead to lower LCC and as a result there is a greater emphasis on the use of LCC assessment as part of the concept (**6.3**) and design and development (**6.4**) stages.*

The quantification of LCC involves the use of complex cost models which cover the factors in great detail, including cost discounting, sensitivity to interest rates and other costs including manpower costs. The scale and complexity of the LCC model used should reflect the overall project scale and complexity. The reliability and maintainability, and LCC work should both draw on the same consistent data so that resulting decisions are valid.

Annex A (informative) Failure patterns

A.1 General

The failure rate for an item is the total number of failures preventing the system from achieving the functions required of it that occur during a defined interval, divided by that interval. If the interval of interest is time, the failure rate is often expressed as FPMH. The interval of interest might vary according to the type of equipment and its application, therefore failures might be monitored over a number of different intervals, such as miles, operations and firings.

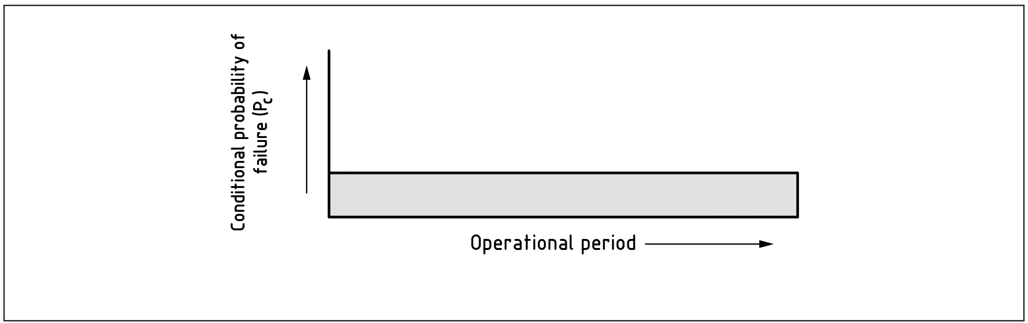
However, likelihood that an item fails at any specific interval can vary through the life of the item as the result of a number of factors. This so-called "failure pattern" takes many forms, but the most commonly used or observed ones are given in **A.2** to **A.5**.

In Figure A.1 to Figure A.6, the failure pattern is represented by the conditional probability of failure as a function of time. The conditional failure probability is the probability that a failure might occur at a specific time, given that no failure has occurred previously. The same principle is applicable no matter what interval measurement is used.

A.2 Random failure

This is the simplest failure pattern and is often called a constant failure rate, as the likelihood of failure of an item is constant throughout its life. This failure pattern is often assumed to be applicable if no other information is available and gives rise to the failure rate being expressed as a mean time between failures (MTBF).

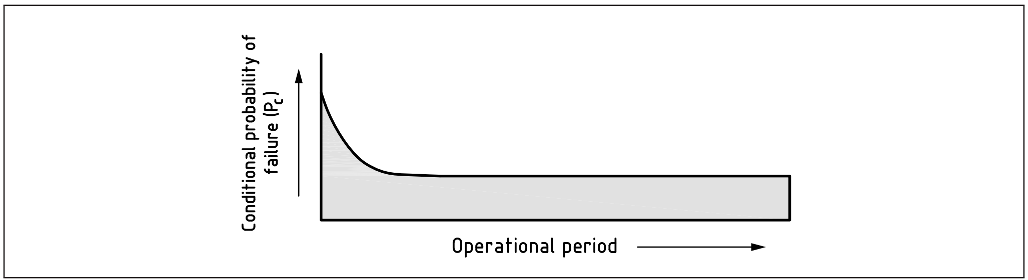
Figure A.1 **Failure pattern: constant failure rate**



A.3 Infant mortality

This pattern represents the case where failures are most likely to happen in the early period of the life of the item and then, after an identifiable period, adopt a constant or slightly increasing failure rate.

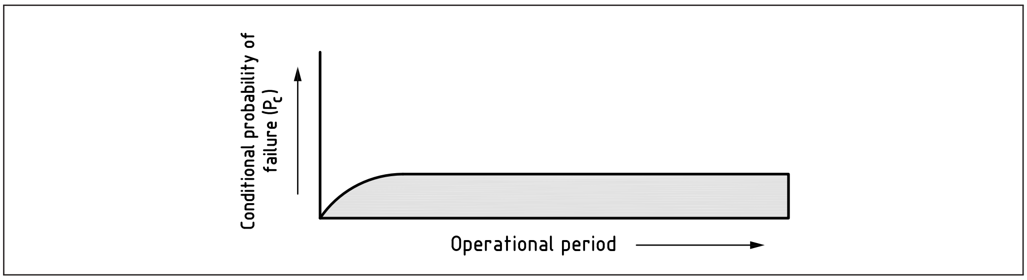
Figure A.2 **Failure pattern: infant mortality**



A.4 Wear-in

This pattern represents the case where failures are least likely to happen in the early period of the life of the item and then, after an identifiable period, adopt a constant or slightly increasing failure rate.

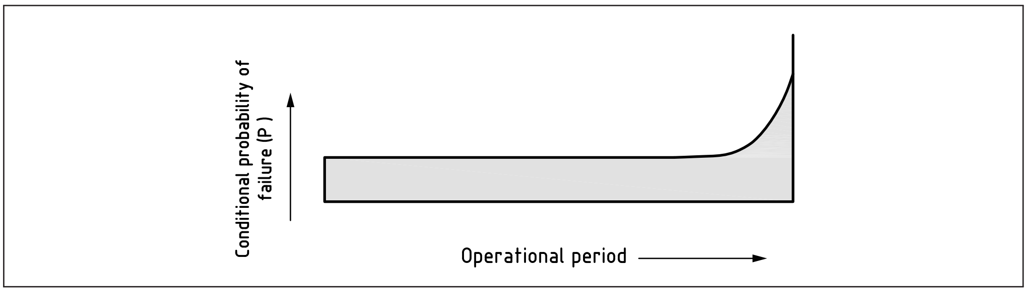
Figure A.3 **Failure pattern: wear-in**



A.5 Wear out

This pattern occurs where an item displays a constant or slightly increasing failure rate for a period of its life and then, at an identifiable age becomes increasingly likely to fail.

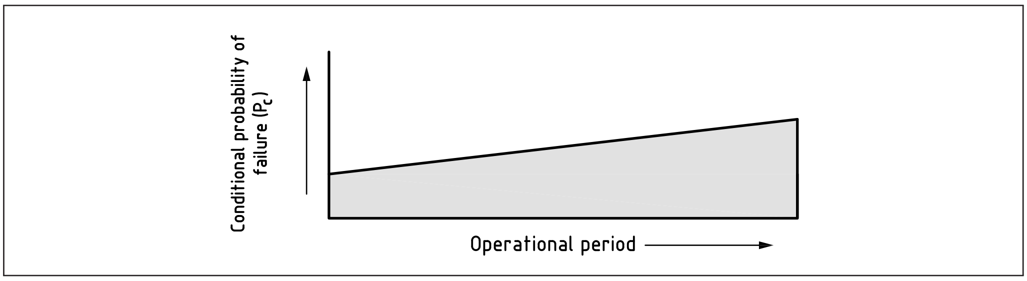
Figure A.4 **Failure pattern: wear out**



A.6 Increasing

This pattern occurs where an item displays a steadily increasing likelihood of failure.

Figure A.5 **Failure pattern: increasing**



A.7 Bath-tub curve

In items, sub-systems or systems that consist of many components, the observed failure rate can often be characterized by the so-called bath-tub curve which is effectively a combination of all of the above patterns:

Research into failure patterns suggests that the majority of failures in modern complex equipment or systems are not age related. Table A.1 illustrates the frequency of occurrence of each failure pattern found by various research activities.

Figure A.6 **Failure pattern: bath-tub curve**

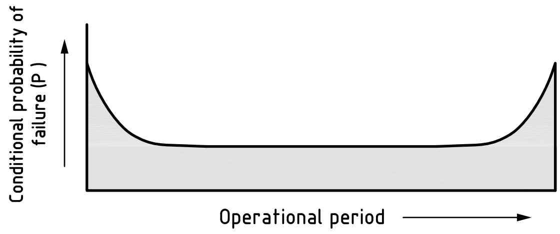


Table A.1 **Failure pattern categories and frequency of occurrence** A)

Failure Pattern	UAL	Broberg	MSP	SUBMEPP
Bathtub	4%	3%	3%	2%
Wear out	2%	1%	17%	10%
Increasing	5%	4%	3%	17%
Wear in	7%	11%	6%	9%
Random	14%	15%	42%	56%
Infant mortality	68%	66%	29%	6%

A) Data source BS EN 60300-3-11.

NOTE For further information on UAL [1], Broberg [2], MSP [3] and SUBMEPP [4] see Bibliography.

Annex B (informative)

Availability

The term availability can be used in a number of ways and has several different mathematical expressions for particular situations. In its simplest form and for an item, which is operating continuously, availability (A) can be calculated as:

$$A = \frac{Up\ time}{Up\ time + Down\ time}$$

Down time is made up of preventive maintenance, active repair, awaiting repair (e.g. waiting for spares or manpower) and downtime due to external factors (e.g. power supply failure).

NOTE 1 Several of these factors are dependent on the support arrangements rather than on the design.

Repair waiting time includes the delay between a failure occurring and having a maintainer ready to start. It also includes delays (for instance, waiting for a spare part) because of remote storage, spares stock-out or possibly a decision not to hold this spare locally.

Availability can be defined by the user in two ways:

- intrinsic availability, which includes the downtime under the control of the designer; and
- operational availability, which includes all contributions to downtime.

NOTE 2 Preventive maintenance is usually excluded because it is assumed to be scheduled so that the resulting downtime occurs during a period when the item is not required.

The procurement and support processes are managed to obtain a figure lying somewhere between the two in order to provide an operational margin.

Annex C (informative) Integrated logistic support

The successful operation of an item in service depends to a large extent upon the effective acquisition and management of logistic support in order to achieve and sustain the required levels of performance and customer satisfaction over the entire life cycle. Logistic support encompasses the activities and resources required to permit operation and maintain an item (hardware and software) in service.

ILS is a management method by which all the logistic support services required by a customer can be brought together in a structured way and in harmony with an item. ILS is applied to ensure that supportability considerations influence the concept and design of an item and to ensure that logistic support arrangements are consistent with the design and each other throughout the item's life. ILS ensures that all the elements contributing to the support of equipment are defined, analyzed and costed for impact on supportability. The following elements are included in ILS:

a) availability, reliability, maintainability and testability;

b) packaging, handling, storage and transportation;

c) safety;

d) LCC;

e) logistic support analysis;

f) spares ranging and scaling;

g) maintenance policy;

h) technical publications;

i) support equipment;

j) personnel;

k) facilities;

l) training; and

m) installation and field support.

Quantification of logistic support costs allows the supplier to define the logistic support cost elements and evaluate the warranty implications. This provides the opportunity to reduce risk and allows logistic support costs to be set at competitive rates.

The conduct of ILS is between the purchaser and the supplier as the supplier cannot impose usage and support conditions on the purchaser of major systems. The supplier also cannot conduct ILS in isolation without knowing in detail the intended use and support of the equipment. Design for supportability can only be optimized if there is a thorough understanding of the structure, skills and costs of the support organization in total.

The successful application of ILS can result in a number of customer and supplier benefits. For the customer, these often include increased satisfaction, lower logistic support costs, greater availability and lower LCC. For the supplier, benefits include lower logistic support costs and a better and more saleable item with fewer item modifications due to supportability deficiencies.

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 5760–18, *Reliability of systems, equipment and components – Part 18: Guide to the demonstration of dependability requirements – The dependability case*

BS EN 60300-3-11, *Dependability management – Application guide – Reliability centred maintenance*

BS CECC 00804:1996, *Harmonized system of quality assessment for electronic components – Interpretation of EN ISO 9000:1994 – Reliability aspects for electronic components*

Other publications

[1] NOWLAN, F.S. and HEAP, H.F. (1978). Reliability-Centred Maintenance. Report AD/A066-579, National Technical Information Service, US Department of Commerce, Springfield, Virginia. (UAL-DOD)

[2] Broberg Study under NASA sponsorship (1973) cited in Failure Diagnosis and Performance Monitoring Vol. 11 edited by L.F. Pau. Marcel-Dekker, 1981.

[3] MSP Age Reliability Analysis Prototype Study by American Management Systems under contract to US Naval Sea Systems Command Surface Warship Directorate reported in 1993, using data from the 1980s Maintenance System (Development) Program.

[4] SUBMEPP reported in 2001, using data largely from 1990s, summarized in US Navy Analysis of Submarine Maintenance Data and the Development of Age and Reliability Profiles, 2001.

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

...making excellence a habit.™