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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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UK Vote

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



56/1884/CD

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SECRETARIAT:
United Kingdom

SECRETARY:
Mr Amit Patel

OF INTEREST TO THE FOLLOWING COMMITTEES:

PROPOSED HORIZONTAL STANDARD:



Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

☐ EMC

☐ ENVIRONMENT

☐ QUALITY ASSURANCE

☐ SAFETY

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TITLE:

Dependability management - Part 3-10: Application guide – Maintainability and maintenance

NOTE FROM TC/SC OFFICERS:

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

DEPENDABILITY MANAGEMENT –

**Part 3-10: Application guide –
Maintainability and maintenance**

FOREWORD

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International Standard IEC 60300-3-10 has been prepared by IEC technical committee 56:Dependability.

This second edition cancels and replaces the first edition published in 2001 This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) This section shall be completed for CDV when the agreed changes are known.

166 The text of this International Standard is based on the following documents:

FDIS	Report on voting
XX/XX/FDIS	XX/XX/RVD

167

168 Full information on the voting for the approval of this International Standard can be found in
169 the report on voting indicated in the above table.

170 This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

171 The committee has decided that the contents of this document will remain unchanged until the
172 stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to
173 the specific document. At this date, the document will be

- 174 – reconfirmed,
- 175 – withdrawn,
- 176 – replaced by a revised edition, or
- 177 – amended.

178

179 The National Committees are requested to note that for this document the stability date
180 is 20XX.

181 THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE
182 DELETED AT THE PUBLICATION STAGE.

183

INTRODUCTION

This document is intended for those responsible for assuring that item design, and the subsequent maintenance related actions, achieve and continue to deliver desired value during use.

Maintainability is defined as the ability of an item to be retained in, or restored to a state to perform as required, under given conditions of use and maintenance. IEV 192-01-27. Maintainability is concerned with the relative ease and economy of time and resources to undertake maintenance actions in a defined context. This context includes both operating and maintenance actions performed by personnel having specified skill levels, using prescribed procedures and resources. Knowledge of those operating and maintenance actions across the item life cycle, is necessary to assure required levels of maintainability established during design.

The relative ease and economy of time and resources relates to the total economic impact resulting from the frequency, timing and duration of maintenance actions necessary to retain inherent levels of safety and reliability and restore those levels when degradation occurs. Such maintenance and associated maintainability characteristics are an inherent feature of the item design within an organizational design context that achieves desired timeliness, cost and quality of support for required operational and maintenance action.

As an inherent characteristic of design, maintainability has an impact throughout the item life and requires trade-off with reliability and availability as well as balancing with other stakeholder requirements such as cost and risk. An early focus on maintenance needs and associated maintainability characteristics and its specification assists in establishing, sustaining, and continually improving the ability of an item to deliver its design intent over its expected life.

Realising the inherent capabilities of an item design requires that the necessary maintenance and operations support capability also be designed, implemented, and continuously evolved to align with external and internal change to the item's configuration and context of use.

DEPENDABILITY MANAGEMENT –

Part 3-10: Application guide – Maintainability and maintenance

1 Scope

This document provides an introduction to maintainability and its relationship with other dependability characteristics of reliability and supportability along with an enabling framework of more detailed standards. The requirements of a maintainability program to achieve a desired balance with other dependability characteristics are described.

This document can be used at any time during an item's life to guide the planning and implementing of a maintainability program focused on achieving an intended balance of performance, cost, risk, and their associated levels of assurance. These outcomes can be explicit in contractual agreements and statutory obligations or implicit in commitments to all stakeholders. All such programs should be tailored to the characteristics of an item, its use and the organizational context of that use.

Guidance is offered on how maintainability programs can be applied at any life cycle stage from new items at the concept stage, to existing items available for commercial procurement, or for items that are part of the way through their operational life.

These programs consider the life cycle implications of a design by formally assessing and treating risks associated with the design and delivery of the maintenance function. Such risks can adversely impact the ability of equipment to deliver value through unacceptable item down time caused by poor design for the maintenance function and also design for its delivery.

This document describes:

- the nature of maintenance and maintainability;
- the role of maintainability characteristics in achieving required item value;
- the potential trade-offs with related dependability characteristics of reliability and supportability that can be made during the life cycle of an item;
- how those trade-offs can achieve a desired balance between required performance, whole life cost, statutory requirements and assurance;
- the role of testability as a subset of maintainability.

Contracts between customer and supplier will vary widely according to conditions and circumstances in different industries. This document is mainly focused on the premise that an item is to be developed by a contractor from a basic concept for the particular requirements of a user. However, in many instances, where an item already exists and needs little or no development effort, the full maintainability programme as described in this document may not be required.

The maintainability program content described in this document can be tailored to suit the needs of the application.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60300-1, *Dependability management – Part 1: Guidance for management and application*

3 Terms, definitions and abbreviations

For the purposes of this document, the terms and definitions given in IEC 60050-192 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- • IEC Electropedia: available at <http://www.electropedia.org/>
- • ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 Terms and definitions

3.1.1

item

subject being considered

Note 1 to entry: The item may be an individual part, component, device, functional unit, equipment, subsystem, or system.

Note 2 to entry: The item may consist of hardware, software, people or any combination thereof.

Note 3 to entry: The item is often comprised of elements that may each be individually considered.

[SOURCE: IEC 60050-192:2014, definition 192-01-01]

3.1.2

maintenance plan

structured and documented set of tasks that include the activities, procedures, resources and the time scale required to carry out maintenance

Note 1 to entry: See also ISO/TR 12489:2013, 3.4.6.

[SOURCE: EN 13306:2010, 2.5, modified – Note 1 to entry has been added.]

3.2 Abbreviations

ATE	automatic test equipment
BIT	built-in test
BITE	built-in test equipment
COTS	Commercial-off-the-shelf
FMEA	failure modes and effects analysis
FMECA	failure modes effects and criticality analysis
FTA	fault tree analysis
ILS	Integrated logistic support
ILSA	Integrated logistic support analysis
ILSP	integrated logistic support plan
LCC	life cycle cost
LORA	level of repair analysis
LRU	line replaceable unit
MLDT	mean logistic delay time
MOTS	military off the shelf
MTTM	mean time to maintain (preventive tasks)
MTTR	mean time to restoration (or repair or recovery)
RCM	reliability centred maintenance
TA	task analysis

4 Maintainability and maintenance overview

4.1 Description of dependability

Dependability is the ability to perform as and when required. A dependable item is one where there is justifiable confidence (developed through analytical and risk based approaches) that an item will operate as desired and satisfy agreed stakeholder expectations. Dependability has many attributes but is usually characterised in terms of reliability, maintainability and supportability (including maintenance, operations and support to both). These attributes may be applied individually or combined into an availability performance measure.

4.2 Description of maintainability

All maintainable items have an inherent maintainability characteristic as a result of their design. The ability of a system to be maintained, that is, retained in or returned to a serviceable condition, is often as important to system dependability as is its ability to perform its intended function reliably.

Maintainability, is thus a measure of the ease and speed with which an item can be restored to operational status having reached a defined failure state. It is a characteristic of the equipment design, construction, installation and commissioning. That maintainability characteristic is influenced by the delivery of the actual operating and maintenance support applied to undertake the restoration activity.

The maintainability measure of an item is the proportion of the maintenance actions undertaken on that item and their time to restore given defined support arrangements. This defined support may include personnel with defined competencies, spares, tools, information, facilities, and logistics applied within a defined organizational context.

4.3 Description of maintenance

Maintenance tasks necessary to achieve the required availability of a system or item need to be identified before a maintainability program can be fully defined and implemented. Not all items are maintainable and are run to failure, many items are unmaintainable after failure by design intent and others because possible maintenance action is not cost effective versus an alternative.

Maintenance is described as the combination of all technical and administrative actions, including supervisory actions, intended to retain an item in, or restore it to, a state in which it can perform a required function. Thus maintenance is either preventive or corrective, meaning retain in or restore to a serviceable condition. A comprehensive description of maintenance and its planning are at Annex A.

Maintenance is most cost effectively achieved by limiting its adverse effects on service or product delivery. This is achieved by:

- designing the item such that maintenance action can be taken while the item is operating without adverse risk exposure;
- providing redundancy to allow for a known period of reduced redundancy when maintenance both preventive and corrective can be done with the item shut down;
- defining shutdown arrangements that allow for efficient packaging of required maintenance tasks for delivery in a defined period at a suitable time.

4.4 Principles

Evaluation and control of maintainability and maintenance is founded on a set of principles. These principles should directly influence the intent, design for, and delivery of an organization's maintenance activity.

These principles are:

- 1) Maintenance tasks are inherent in a design solution.
 - This principle requires that maintenance tasks are to:
 - a) be determined using risk based techniques;

- b) be aligned to organizational intent;
c) demonstrate achievement of value.
- 2) Maintenance tasks and their delivery are to be determined in a structured manner.
All maintenance tasks exist to achieve value as identified by a risk based process. This principle requires that all maintenance tasks:
- a) are determined using a defensible process;
a) demonstrably achieve value;
b) account for human capability including physical, mental and behavioural;
c) are designed for efficient and effective delivery;
d) account for their impact on item functional requirements.
- 3) Maintainability can be measured as a probability distribution of defined maintenance task times.
Maintainability typically requires a mathematical connection to Reliability, Supportability, and subsequently Availability. This principle requires that when defining a maintenance task the:
- a) derivation of task duration is defensible;
b) task duration can be measured and verified.
- 4) Maintainability can be balanced against dependability characteristics of Reliability and Supportability to achieve design assurance intent as measured by Availability.
Intended maintenance actions and tasks represent a balance between the cost of the task, the assurance level desired and the risk reduction achieved. This principle requires that for all maintenance tasks:
- a) there is an understanding of other dependability and organizational objectives;
b) analyses and studies are tailored to context;
c) an understanding exists of the desired balance and how this is to be evaluated.
- 5) Maintainability requirements may evolve during use to ensure that the item continues to meet stakeholder requirements.
During the use of an item the environment, stakeholder requirements and other factors may change and thus continued achievement of maintainability will need to be re-evaluated.

4.5 Benefits

Benefits from evaluating and controlling maintainability include:

- providing justifiable confidence that the maintainability of items will be as required, when required;
- managing the risks of failure or degraded performance in a cost-effective way to achieve a balance of cost, risk and performance;
- enabling design weaknesses to be identified and improved with consideration for performance, risk and through life cost;
- providing information and data that support the continual improvement of maintainability performance;
- establishing an appropriate and cost effective maintenance programme;
- reduced item down time resulting in improved availability;
- reduced maintenance effort;
- improved timeliness of maintenance delivery;
- improved quality of maintenance effort;
- improved reliability from quality maintenance;

– improved safety of maintenance personnel.

4.6 Interfaces

4.6.1 General

Reliability, maintainability and supportability each have influencing interfaces on the other. The two interfaces that relate to maintainability are reliability and supportability.

4.6.2 Effect of maintenance on reliability

Maintenance is intended to manage the consequences of item failures. Maintenance cannot change the inherent reliability or maintainability characteristics of the item but can influence the operational outcomes.

Maintenance of a product will not influence its inherent reliability but it may influence its operational reliability. Inherent reliability assumes the product receives perfect maintenance and represents “a measure of reliability that includes only the effects of an item design and its application, and does not account for effects of the operational and support environment”. This is sometimes referred to as “intrinsic or inherent” reliability”.

Reliability block diagrams can be used to assess the impact of partial repair that result in elements of the item having a lower reliability or the conduct of additional maintenance actions that, while not cost effective, may achieve a target level of operational reliability that is greater than the optimal design intent.

Repairs to items that have a random failure pattern failure characteristic will not influence the operational performance of the item unless they introduce additional degradation or defects.

Any maintenance intervention brings the likelihood of reducing operational reliability through either human error (task done incorrectly without intent) and or human violation (tasks not done or not done as described). Such impacts may affect both preventive maintenance and corrective maintenance outcomes.

Such effects may be quantified by such values as task effectiveness resulting from human performance or again the likelihood of human violation resulting from organizational culture issues. In these cases, the task effectiveness may relate to the either the likely success in identifying that a conditional threshold measure has been exceeded or a repair task has been effective in returning the item to its intrinsic reliability.

4.6.3 Effect of maintenance on supportability

The quantum of maintenance to be conducted on an item is determined by its failure modes and the reliability and maintainability characteristics of those modes. This quantum of effort, whether preventive or corrective in nature, will determine the supportability of the item in terms of the following attributes for the defined maintenance support, being:

- quality of delivery;
- timeliness of delivery;
- cost of delivery.

Quality of delivery refers to the conduct of the task in accordance with authorised descriptive media which may be words, video or some other equivalent information source. The potential for either human error or human violation to vary the authorised task content should be known so as to assess that quality. Quality relates not only to compliance with the task content but the use of all integrated support defined for that task including spares, tools, facilities and logistics such as warehousing, transport, packaging and handling.

Timeliness of delivery refers to the time delay between the identified failure event and the completion of all preparatory activity necessary to the actual conduct of the maintenance task. For unplanned repair tasks this period would include:

- notification of task;
- permit to work;
- assembly of material, spares, tools and task information;

- travel to site;
- unloading and transport to work position of any required support equipment such as tools and plant.

Cost of delivery refers to the affordability of all actions defined for the maintenance task. Imbalance between purchase price and ongoing cost of ownership can result in future costs of maintenance being unaffordable and hence threaten achievement of inherent characteristics of reliability and supportability through lack of proper funding.

5 Maintenance program

5.1 Overview

The purpose and key benefits of a maintenance program are to:

- Identify what preventive and corrective maintenance is required to achieve the required levels of reliability and availability specified for an item;
- Inform the maintainability program of what maintenance will be undertaken on which items and how often;
- improve availability of items and hence potential value to stakeholders through balanced maintenance programs;
- reduce maintenance effort and related human resources through the maintenance task packaging for efficient delivery and reduced overheads;
- reduce life cycle cost;
- provide information necessary to ongoing maintenance management and continuous improvement.

The core content of a maintenance program requires development of four key components being:

- Failure mode and effects analysis (IEC 60812) or equivalent risk based assessment of risk exposure such as a HAZOP study (IEC 61882) to identify what failures can occur in the use context of the item;
- Level of Repair Analysis (LORA) to determine what corrective maintenance actions are necessary to return failed or degraded items to a serviceable status rather than replace with new items;
- Reliability Centred Maintenance (IEC 60300-3-11) analysis and/or Risk Based Inspections to manage the consequences of failures identified in the FMEA/FMECA;
- task analysis to describe the task content, packaging requirements, and define the safety and quality aspects of the task to assure cost effective delivery and satisfaction of a duty of care.

5.2 Maintenance program management

In order to achieve a cost-effective maintenance outcome, the development program should be implemented, in a planned and systematic manner, in conjunction with the maintainability program and the reliability program. These item support aspects should be integrated with the overall item design program. There are five basic components in such a program which are described in the following clauses.

5.3 Specification of requirements

The maintenance program will need to be tailored for a specific item or project, giving appropriate consideration to the relevant conditions, requirements and complexity. The full maintenance requirements development program described in the following paragraphs, would only be applied to a large and complex item being developed from the concept stage to production. For less complex products, or the application of existing designs, a simpler program can be achieved by using only those parts of the program, which are applicable to the technical and business context.

5.4 Maintenance framework

The maintenance policy and maintenance concept documents become the basis for preparation of the maintenance requirements analysis and subsequent maintainability design effort. The item specification, statement of work and supporting concept of operations, which includes the maintenance concept, should capture the broad maintenance concept for the item to be procured, such as:

- anticipated levels of maintenance support to inform the logistic support effort;
- assignment of responsibility for support functions;
- general repair policies and constraints such as engineering and design authorities;
- logistic support to be applied to the maintenance function such as use of existing plant or test equipment and an associated test philosophy i.e. built in or manual;
- effectiveness measures associated with the support delivery such as supply chain responsiveness, facility utilization, test equipment availability and reliability, human factors such as error and violation rates.

A more detailed description of the maintenance framework is provided at Annex B Maintenance Process.

5.5 Measures of maintenance

Maintenance can be measured in both qualitative and quantitative terms. Such measures relate to compliance such as quality, cost and timeliness of completion. Other measures relate to outcomes such as rate of conditional failures discovered and rate of operational failures achieved.

Qualitative measures may relate to relative industry benchmarking and provide a comparison in terms of quartile positioning by industry or technology. The measures may relate to effort, cost or downtime and seek to provide evidence for improvement opportunities.

Quantitative measures are often required as part of such practices as performance based contracting where actual measures of both inputs to, and outputs from, the maintenance function are defined in quantitative terms. Examples include percentage of planned tasks completed on time and to cost, and ratios of planned to unplanned maintenance tasks to assess level of maintenance program effectiveness in managing failure consequences.

5.6 Maintenance in design

In achieving an operational outcome for a defined design solution, the maintenance program is an essential input to achieving the operational intent of the design. Inability to manage the consequences of failure by transforming potential functional failures into discovered or eliminated failures will challenge achievement of required operational availability. Likewise, failure to translate known maintenance effort into a suitable Supportability program will likely prevent achievement of intended operational outcomes.

The maintenance program should develop progressively across the lifecycle using the FMECA tailoring process (IEC 60812:2018) to determine the particular approach selected from the top down/bottom up and qualitative/quantitative quadrant in Annex A. The FMECA outcomes can then inform the LORA and RCM analyses defining a maintenance and operational commit which becomes the basis of assessing the life cycle costing comparisons of alternate design solutions.

5.7 Maintenance verification

Compliance with the specified maintenance requirements can be demonstrated through a verification process that:

- verifies and updates the contractor's maintenance requirements model and associated task decision algorithms,
- implements economical correction of design deficiencies to provide assurance that maintenance requirements will be achieved and demonstrated, and

- provides progressive assurance that the integrated support plan, which is directly related to the maintenance remit, is valid.

This function as it relates to both maintenance and the subsequent maintainability design solution is described in greater detail at Clause 8.

6 Maintainability program

6.1 Overview

The purpose and key benefits of a maintainability program are to:

- improve availability of items and hence potential value to stakeholders;
- reduce maintenance effort and related human resources;
- reduce life cycle cost;
- provide information necessary to ongoing maintenance management and continuous improvement.

An effective maintainability program should be planned, integrated, and developed together with other design, development and production functions to assure delivery of organizational objectives. The program content and structure should be selected to match the constraints of the application and the expected potential importance of maintenance in the item life cycle.

Only those tasks, which are expected to provide a positive return on investment, should be included in the program. Such structuring should be consistent with the criticality of the output, the complexity of the design, the level of technical innovation and the production techniques to be applied.

Note 1: The full program described in this document would only be applied to a major complex product with the potential for long- term usage. For less complex maintainable products, a simpler program should be adopted by tailoring the program to suit the degree of complexity and the requirements of the customer

Note 2: Related IEC standards and guides, notably IEC 60706-5, can be used as reference documents or tools to provide more detail as to how a particular maintainability program task should be undertaken

Note 3: Existing items generally need little or no development effort, hence the full maintainability program as described in this document should not be required.

The program should be integrated with related development tasks such as maintenance requirements determination and support analysis to assure best use of resources. Typical project resources would include:

- required managerial and technical capabilities to do defined tasks;
- plans that define those tasks, their durations and associated milestones to give clear direction;
- processes necessary to guide the conduct of defined tasks;
- program governance to assure program delivery.

Note 1: Support analysis and maintenance requirements determination both require effort to identify maintenance tasks and resource applications necessary to a maintainability program. Care should be taken that such information is efficiently shared and not recreated unnecessarily.

6.2 Management

In order to achieve acceptable maintainability in a planned and systematic manner, a maintainability program, in conjunction with a reliability program, should be integrated with the overall project design process. There are six basic responsibilities in such a program including:

- assigning responsibility for maintainability to a competent person;
- providing adequate resources, including analysis tools, to undertake the program;
- maintaining sound communication with internal and external stakeholders;
- integrating the program into overall product development or improvement;
- establishing controls for suppliers to the program;
- supporting continuous improvement.

Such a maintainability program should at least have the following elements:

- management and organizational activities to ensure effective and efficient implementation of the program;
- a set of maintainability analysis tasks to be performed during the design process;
- specialist support activities to provide the necessary information for the program;
- transitioning arrangements that allow application of continuous improvement actions during item use.

The objectives of such a program should be to balance system effectiveness with respect to the following constraints:

- trading product availability against possible LCC impacts;
- trading maintenance and support requirements against possible LCC impacts;
- eliminating safety hazards in accord with statutory direction.

6.3 Specification of program requirements

The maintainability program will need to be tailored for a specific item or project, giving appropriate consideration to the relevant conditions, requirements and complexity. The full maintainability program described in the following paragraphs would only be applied to a large and complex item being developed from the concept stage to production. For less complex products, or the application of existing designs, a simpler program can be achieved by using only those parts of the program, which are applicable to the technical and business context.

Planning an effective maintainability program during any of the product life cycle stages requires knowledge of maintainability principles, methods and techniques. It also requires an understanding of the item itself and its technology, its intended use, its various related cost factors, its design and customer expectations. In order to obtain effective results, maintainability activities should be integrated with the other design and development activities rather than managed separately.

Maintainability considerations depend on requirements such as item life, reliability, safety and availability and on the financial considerations related to different market situations. For example, flight systems and nuclear power plants require a high degree of safety, which drive maintenance requirements. With other products, the cost of maintenance related to the operating cost can be the significant factor, which determines the degree of maintainability required.

All maintainability programs must be tailored to their context. This contextual tailoring can require the following factors to be taken into account during the maintainability program development:

- maintainability requirements: The level of maintainability performance;
- complexity: The complexity of an item will determine the complexity of the maintainability program. For example, the degree of testability will depend on the level of diagnostic capability required;
- maturity: Mature items such as COTS will have well-established maintenance procedures, but for less mature products account has to be taken of the extent of unproven technology and the need to develop and assess procedures appropriate to the design;
- technical constraints: When the design is constrained by technical or physical parameters beyond the control of the designer, more complex maintenance action can be required;
- program constraints: Tight schedules or funding limitations can restrict freedom of design when seeking balanced outcomes.
- maintenance support conditions: The maintenance plan and personnel skill levels of staff available to the operator can influence task effectiveness and hence MTTR and MaxTTR;
- operational conditions: Environmental severity, time in use and operating cycles can govern the frequency of maintenance action and hence the maintainability solution;