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To: National Standardisation Bodies and Collaborating Partners

Secretary Enquiry

CEN/CLC European Standard

prEN 45554 - General methods for the assessment of the ability to repair, reuse and upgrade energy related products.

National Standardisation Bodies and Collaborating Partners are invited to comment on the document. Comments can be considered only if form sheet (FormComments.doc) is used.

National Standardisation Bodies and Collaborating Partners shall upload their comments, as a reply to this document on the Collaboration tool, no later than 2017-11-23.

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Foreword

Introduction

WORKING NOTE: INTRODUCTION TO BE COMPLETED AFTER POTENTIAL COORDINATION WITH OTHER JTC10 WGs

This standard, along with the standards of the CEN-CLC XXXXX series, has been developed under Mandate M/543 of the European Commission.

CEN, CENELEC and ETSI were requested by M/543 to develop horizontal standards and standardisation deliverables for energy-related products in support of implementation of the Ecodesign Directive (2009/125/EC) and to contribute to the transition towards a more circular economy. The standards developed under M/543 will be the baseline for future product publications covering specific energy-related products (ErP) or groups of related ErPs. The primary addressee of the standards in the CEN-CLC XXXXX series are experts preparing product specific publications on the various covered topics.

Topics covered in the CEN-CLC XXXXX series are inter alia, product durability, reparability, reusability, recyclability, recycled content, ability to remanufacture, and product lifespan. While various important topics in the context of material efficiency are covered in the standards of the CEN-CLC XXXXX series, other subjects of material efficiency, e.g. renewable resources, biodegradable plastics, light weighting and multi functionality, are not covered for the moment, despite their potential impact on material efficiency.

As ErP can often not be completely recycled and the benefits associated with material recovery cannot fully compensate the energy (and material) demand of the whole production chain, each disposed ErP also means losses in energy and materials. Especially precious and special metals are at present recycled only to a very limited extent and plastics are mainly used for energy recovery.

As ErP can often not be completely recycled and the benefits associated with material recovery cannot fully compensate the energy (and material) demand of the whole production chain, each disposed ErP also means losses in energy and materials. Especially precious and special metals are at present recycled only to a very limited extent and plastics are mainly used for energy recovery.

Therefore securing a minimum technical life time or prolonging useful life by repair and reuse are relevant contributions to resource efficiency of energy-related products. Improving recyclability of ErP or use of recycled materials in product manufacturing contribute to better close material cycles.

In order to ensure that measures indeed reduce the environmental impact related to ErPs the entire life cycle of an ErP needs to be considered. In the case of prolonging useful life this includes for example the evaluation of trade-offs between longer lifetime and reduced environmental impacts of new products. Considerations such as these are addressed in the preparatory studies commissioned under Directive 2009/125/EC, which include life cycle assessment and life cycle costing. Whilst such aspects establish a relevant context for this standard, they are not addressed in detail.

In this standard, common elements for reusability, reparability and upgradeability such as an evaluation of ease of disassembly are addressed at a part and product level. Quantitative (index-related) evaluation and qualitative (checklist / scoring based evaluations) options for evaluation of reusability, reparability and upgradability are considered.

This standard is especially linked to the horizontal standards on “durability” and “Ability to re-manufacture” that have been published under CEN-CLC XXXXX series.

1 Scope

This standard provides non product-specific parameters and methods relevant for Energy-related Products (ErP) to assess:

1. the ability to repair products
2. the ability to reuse products, or parts thereof,
3. the ability to upgrade products, excluding remanufacturing.

It specifically includes horizontal/generic parameters and methods relevant for assessing the ability to access or remove certain parts, accessories or consumables from products to facilitate repair, reuse or upgrading.

The parameters and methods in this standard focus on the design of the product and related conditions when the product is placed on the market, taking into account knowledge of parts that are likely to fail or need replacing, or have reuse potential.

This standard is general in nature. It is not intended to be directly applied, but may be cited together with product-specific or product group harmonised standards.

This standard provides a framework to guide vertical standardisation groups in the development of product group specific methods for assessing the ability of Energy-related Products to be repaired, upgraded or prepared for re-use. It offers a toolbox of parameters and methods to choose from as needed by Technical Committees.

2 Normative references

WORKING NOTE: LIST FORESEEN TO BE EXPANDED TO INCLUDE AT LEAST THE STANDARD DEVELOPED BY JTC10/WG2 IN ACCORDANCE WITH https://boss.cen.eu/ref/IR3_E.pdf

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Zandin, Kjell B (2003). *MOST Work Measurement Systems*. New York: Marcel Dekker. ISBN 0-8247-0953-5.

IEEE 1874:2013 *Standard for Documentation Schema for Repair and Assembly of Electronic Devices - "oManual"*; licensed under the Creative Commons attribution license (CC-BY 4.0; https://creativecommons.org/licenses/by/4.0/).

Directive 1999/44/EC on consumer sales and guarantees (http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1441982346675&uri=CELEX:01999L0044-20111212; consolidated version)

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

3.1
Part
Component or assembly .
Note 1 to entry: The term "part" will be used, unless assembly or component provides further necessary clarification.

Note 2 to entry: software, consumables and accessories are not considered parts

3.2
Assembly
set of components assembled into a single part.
[SOURCE: IEC 62542 definition 3.2, modified to cover more than “electronic assembly”]

3.3
Component
part of a product that cannot be taken apart without destruction or impairment of its intended use.
[SOURCE IEC 62542 definition 3.3, modified to cover more than “electronic component”]

3.4
Consumable
product content that is foreseen to be frequently replaced or refilled during the normal life time of the product.
EXAMPLE: filter, filter bag, ink or toner, lubricant, refrigerants and heat exchange liquid/gas...

3.5
Accessory
device supplementing a main device or apparatus, by adding to its functionality as an add-on or exchangeable device.
Note 1 to entry: this standard only considers accessories supplied or recommended by the manufacturer of the main product
[SOURCE: 151-11-24, modified]

3.6
Direct re-use
use, by a person other than its previous owner or user, of products for the same purpose for which they were conceived without any preparation for reuse, except minimal cleaning and adjustments that can be performed by the owner himself, e.g. a data wipe of any product which can contain personal settings.
Note 1 to entry: products subject to direct re-use are also called “second hand” products

3.7
Disassemblibility
characteristic of a product which can be disassembled in several parts, and subsequently be reassembled (with the same or equivalent parts) and made operational.

3.8
Disassembly
process whereby an item is taken apart in such a way that it could subsequently be reassembled and made operational.
[SOURCE: IEC 62542 definition 6.1, modified by deleting the note]

3.9
Disjointment
process whereby materials are separated by mechanical means such that the item cannot subsequently be reassembled to make it operational.
Note 1 to entry: The process typically employs actions such as cutting, grinding, scratching and abrasive processes.
[SOURCE: IEC 62542 definition 6.2]

3.10
Maintenance
set of procedures to ensure the serviceability of a product.
Note 1 to entry: the word “maintenance” is sometimes reserved for “preventive maintenance”
[SOURCE: ISO 4306-1:1990, definition 5.1, modified by addition of the note 1 to entry]

3.11
Preparation for re-use
sequence of operations by which products, or parts thereof, are prepared so that they can be used by a person other than its previous owner or user, for the same purpose for which they were conceived

Note 1 to entry: preparation for re-use of products consists in cleaning, testing, repairing, etc. and can apply to both hardware and software settings and updates.
Note 2 to entry: preparation for re-use of parts or components consists in extracting them from the product where they are installed so that they can be used to build or repair other products.
Note 3 to entry: “preparation for re-use” has a specific meaning and is subject to specific requirements for products in scope of the WEEE Directive (2008/98/EC); see EN 50614 for more details.

3.12
Reusability
characteristic of a product that allows all or some of its parts or the product as a whole to be used again for the same purpose

3.13
Re-use
any operation by which products or parts thereof are used again for the same purpose for which they were conceived

3.14
Refurbishing
functional or aesthetical maintenance or repair of an item to restore to original, upgraded, or other predetermined form and functionality
[SOURCE: IEC 62542 definition 6.11]

3.15
Remanufacture
production process that creates products using parts taken from previously used products
[SOURCE: IEC 62542 definition 6.12]

3.16
Repair
process of returning the product to serviceability
Note 1 to entry: “repair” is sometimes referred to as “corrective maintenance”
[SOURCE: ISO 4306-1:1990, definition 5.2, modified by addition of the note 1 to entry]

3.17
Reparability
characteristic of a product that allows all or some of its parts to be separately repaired or replaced without having to replace the entire product

3.18
Replaceable part
Part of a product, that can be replaced in order to repair or upgrade a product.
Note: 1: Replacement of parts can also refer to the replacement of software, accessories and consumables.

3.1.19
Serviceability
ability of a product to perform the specified functions
[SOURCE: ISO 4306-1:1990, definition 1.2]

3.20
Spare part
part which can replace a faulty, failed or worn-out replaceable part.

3.21
Upgradability
characteristic of a product that allows all or some of its parts to be separately upgraded or replaced without having to replace the entire product
[SOURCE: ISO 14021:1999, definition 3.1.4, modified (replaced “its modules or parts” by “all or some of its parts”)]

3.22
Upgrade
Upgrading
process to enhance the functionality or capacity of a product
Note 1 to entry: upgrading may involve hardware as well as software
[SOURCE: IEC 62075:2012, definition 3.23, modified by addition of note 1 to entry

4 How to use this standard

This general standard provides a framework for the development of parameters and methods for assessing Reusability, Reparability and Upgradability (RRU) of specific groups of products.

The normative part of this standard describes aspects and parameters influencing the RRU of products. . These are generic and shall not apply as such to all Energy-related Products. However, they may be used as references by regulators and product specific standards committees when addressing specific groups of products.

The informative annexes of this standard provide more detailed information on parameters and methods of the framework. These offer a toolbox to choose from as deemed appropriate for the development of product specific standards.

Parameters and methods covered in this standard can be grouped in three main assessment options:

1. Qualitative assessment, i.e. evaluating the existence of specific attributes associated to the product
2. Semi-quantitative assessment, i.e. individual or combined quantification of quality levels of one or more attributes associated to the product
3. Quantitative assessment, i.e. numeric measuring of the degree to which an attribute is addressed in the product (e.g. indices)

Qualitative assessment can be suitable for the development of product specific checklists, although differentiation between products could be limited. Semi-quantitative and quantitative assessment in contrast can allow for a more comprehensive assessment although at the expense of more complexity.

5 General considerations

5.1 General considerations for the assessment of RRU

The range of possible repairs and upgrades varies between those performed by professionally skilled individuals in a specialised setting and those that can be managed by consumers in a home environment. This is similarly the case for the removal of a component for reuse, where the extent of reusability of components will be very different for a consumer compared to a professional repairer or remanufacturer.

In chapter 7 a list of relevant parameters influencing RRU is provided, differentiating by those related to product design (e.g. tools, skills, service environment) and those related to service conditions (e.g. availability of spare parts and provision of information). A classification as a function of possible repair conditions and actors is proposed for each parameter.

The wider the range of actors that a product design allows for repair, upgrade or preparation for re-use processes, the broader is the range of repair scenarios possible. Repair options are likely to be more accessible for a product that can be repaired, upgraded or prepared for reuse by actors having a lower level of skill category or when common tools are needed.

The parameters and classification listed under chapter 7 shall equally apply to reparability, reusability and upgradeability. The relevance of each parameter and appropriateness of a classification for a specific product group shall be assessed on product-by-product basis according to the characteristics of the product group under study. This list of parameters and their classification shall be considered as non-exhaustive.

TCs should carefully assess priority parts, together with applicable parameters and classification, as well as any methods for assessing RRU they wish to develop.

5.2 General considerations on reparability

Assessments of reparability can take place at three levels, at part level, at product level and in terms of the service that accompanies the product.

Services accompanying the product are prerequisites for reparability:

1. Availability of adequate repair instructions
    a. Troubleshooting instructions
    b. Disassembly and repair instructions
    c. Information on spare parts
    d. Information on testing, resetting and restarting
2. Availability of spare parts needed
3. Availability of software and firmware updates

At product level reparability is determined by:

1. The fraction of parts of the product that can be repaired,
2. Reparability at part level
3. Products interface for fault diagnostics, programming and resetting
    a. The time needed to identifying the repair needed upon failure of the product
    b. The time needed to test, reset and restart after repair of the product

At part level reparability is determined by:

1. The average occurrence of failure of the part
2. The time needed to do disassembly/ies, depending on
    a. Number of disassembly steps and manipulations
    b. Time to undo any fastenings
3. Time to do repair activities
4. The time needed to do reassembly/ies, depending on
    a. Number of disassembly steps and manipulations
    b. Time to close any fastening
5. The average occurrence of failure of any part during disassembly and reassembly.

Reparability is also influenced by:

1. Tools needed for disassembly to gain access to parts that failed
2. Workshop environment related to safety of the product and the repairer (e.g. clean room, ESD safe environment or dust extraction)
3. Repairers' ability/skills

5.3 General considerations on reusability

For reuse two situations can occur:

- direct reusability of whole products and
- harvesting of reusable parts for potential reuse of parts as spare parts or for remanufacture.

NOTE: Remanufacture and remanufacturability are out of the scope of this document, but are treated in prEN45554 - General method for assessing the ability to remanufacture.

NOTE: Traceability of reused components in the value chain is essential for verification of any claims to third parties about the incorporation of reused components in products. Assessing the portion of reused components in products and traceability reused components in the value chain is outside the scope of this standard, but is treated in prEN45556 -- General method for assessing the proportion of reused components in energy related products.

Reusability could be a function of upgradeability and/or reparability, as well as durability. TCs should decide on the appropriateness of including upgradeability, reparability and/or durability as part of the assessment of reusability for a specific product group according to the characteristics of the product group under study.

NOTE: Durability of parts or products is essential for reuse or remanufacture of parts or products. Assessing durability is outside the scope of this standard, but is treated in prEN45552 -- General method for the assessment of the durability of energy related products.

If a TC decides to do assessments of reusability as a function of reparability and upgradeability, it can take place at the parts level, at the product level and in terms of the service that accompanies the product. This is described in point 4.3 and point 4.4. Additional information for parts or products should be available on:

- availability firmware and software updates
- part-coding to identify parts suitable for reuse
- testing and resetting for reuse
- how to wipe any personal data
- minimal cleaning and adjustments

Also the following differences should be noted: average occurrence of failure of the part is relevant, but contrary to reparability, reusability is more relevant for a part with lower failure rates and longer wear out times

If the intention is to establish direct reusability of whole products for either direct reuse or refurbishment, the pre-requisite is that the product is in good working order and allows transfer of ownership without transfer of any personal data.

Where data is stored on storage internal to the product, secure data deletion tools should be pre-installed or build in or made available which permanently delete all user data without compromising the functionality of the device for further use.

Simplified transfer of data from an old to a new product is made available via installed or downloadable tools such as an application, a cloud based service or instructions detailing a manual process.

5.4 General considerations on upgradeability

As reparability, assessments of upgradeability can take place at part level, at product level and in terms of the service that accompanies the product. This is described in point 4.3. The following differences should be noted:

- upgradability should explicitly include availability firmware and software updates.
- upgrades will be needed, not spare parts
- troubleshoot instructions and failure diagnostics upon failure will not be required
- average occurrence of failure of the part is less relevant, but technology changes and changes in use profiles over life time of the product are

6 Definition of parts that are relevant for the RRU assessment

Reusability, Reparability and Upgradability (RRU) shall be considered in a targeted way. The term priority is used to indicate those parts that are deemed to be generally more relevant for RRU.

Unless a list of priority parts is defined through a regulatory process or can be established for the development of product specific standards with which to assess RRU, all parts need to be assessed.

When no list is available, a 3 step process shall be followed:

1. Identify and list parts of a given product category that are more prone to be replaced, repaired, re-used or upgraded
2. Assess the value of replacing parts
3. Rank parts in a priority list

6.1 Identify and list parts prone to be replaced, repaired, reused or upgraded

The starting point shall be a preliminary list of potentially priority parts that are more prone to be replaced, repaired, re-used or upgraded for a given product group.

This shall come from manufacturers and the literature. Alternatively, the list may be established based on a physical disassembly exercise.

Potential priority parts can either be hardware, software or both. Software shall be considered only when meeting the following conditions:

- It is related to one of the functions specified by the manufacturer, and
- It is supplied, recommended or supported by the manufacturer

Note 1: “third party applications (apps)” generally do not meet those conditions and therefore should not be included in such list of potentially priority parts.

Priority parts shall also include consumables and accessories, unless specified otherwise.

6.2 Assess the value of parts

The value of having a part replaceable or upgradeable is highly dependent on the likelihood that such a replacement is needed for repairing or upgrading the product during its lifetime.

Relevant data shall be collected that allows assessing the likelihood that parts need to be replaced or repaired during that time. Data may be based on statistical surveys, calculations (e.g. MTBF) or experimental data. Part failure, accidental breakdowns and normal wear-out shall be considered. More details can be found in the Durability standard prEN45552. A list of key features typically upgraded in the product group shall also be compiled.

The value of a part can be influenced by:

1. Part/product characteristics (part failure rate, functional criticality, ease of disassembly)
2. Environmental and economic factors (environmental impacts and economic value)
3. Other aspects (e.g. technical development and aesthetic appearance)

A cut-off rule shall be set to select the most important parts which to focus on.

6.2.1 Repair

Evaluation of parts for repair should focus on the average occurrence of failure of the part, taking also into account random failures and wear out characteristics.

EXAMPLE 1: Part failure covers all cases where a part unexpectedly fails, in absence of accidental breakdown or normal wear-out.

EXAMPLE 2 accidental breakdowns cover cases where the part is broken by a cause external to the product, regardless its age or the one of the whole product. Typical example is the glass of a screen or display, which can be damaged by a fall, scratches and other shocks or contacts.

EXAMPLE 3: Normal wear-out concerns parts with a lifetime (expressed as a time or as a number of cycles) knowingly shorter than the one of the product itself. Typical example is the battery, which usually has a limited number of charging cycles, after which its capacity significantly drops.

The following information shall be collected:

- Main functions / sub functions / parts
- Typical limiting states, failures and misuses
- Typical frequency of failures modes and impacted components

- Frequency of repair and temporal distribution;
- Repair operations requiring the replacement of components and disassembly steps number or difficulty;

Based upon this information, relative weights can be assigned to the relevant parts as appropriate.

For each identified priority part, it shall be clearly specified under which conditions a given part is deemed to be a priority part for an entire product group. This is important in order to differentiate between different technologies that might be used for a given priority part.

Example for the clear specification of priority parts include

"Nickel Metal Hydride batteries with a cycle life below X cycles"

"Brushed electric motors"

6.2.2 Reuse

In the case of reuse there are two levels of consideration:

- **Parts reuse:** Identification of priority parts for extraction and reuse
  - The durability analysis for Prioritisation of parts for repair (point 6.2.1 - Evaluation of importance of replaceable parts for repair) can be used to identify parts with low failure rate and long wear out time.
- **Whole product reuse:** Identification of parts for repair and upgrading to enable product reuse.
  - In the event of a fault with the product, the prioritisation for repair can be followed.
  - In the event that a working product is intended to be upgraded in preparation for reuse, the Prioritisation of parts for upgrading (point 6.2.3 - Evaluation of importance of replaceable parts for upgrading) can be followed.

For reusability of components the boundaries comprise at least the replaceable parts for which spares are available. A manufacturer may declare more parts of a product, or even the entire product, reusable if this information is given, justifying the relevance of such reuse, e.g. existing markets for used parts or remanufacturing activities.

6.2.3 Upgrading

Evaluation of parts for upgrading is expected to focus mainly, but not necessarily, on parts subject to rapid technology changes or changes in use profiles over life time of the product.

In order to identify priority parts for upgrade purposes, insights from a range of sources should be used to identify and rank:

- **Typical upgrade features and frequency of upgrade**
- **Product replacement motivations**: The typical reasons for products being replaced even although they still function as originally intended
  - Sources of information can include for example online forums, field experience, consumer surveys, consumer testing activities and expert judgement in TCs developing product specific upgradability standards
- **Repair to upgrade options**: The priority parts for repair are analysed for their potential to be replaced with enhanced functionality or capacity.

6.3 Ranking parts in a priority list

After establishing a list of priority parts, it shall be assessed if these can be ranked or weighted according to their importance in terms of RRU using criteria suggested in the previous chapter.

7 Classification of parameter for the assessment of RRU

7.1 Introduction

This chapter gives an overview of the parameters that should be considered in the course of writing product-group specific standards. The parameters listed below may be compiled in a product specific checklist of pass/fail requirements.

Method options for assessing the ability to repair, upgrade or re-use according to the selected parameters are reported in Annex B. It also provides an example of a scoring system for the semi-quantitative and quantitative assessment of RRU, which provides guidelines for the development of product specific methods.

7.2 Product design-related parameters for assessing RRU

Product design parameters can have a significant influence on the ability to disassemble priority components from a product for the purpose of repair, reuse or upgrade, which can be referred to also as disassemblability.

Parameters influencing the disassemblability of a product can be for example type and number of fasteners and tools, which will influence the amount of work required to disassemble until the parts to be removed, repaired or changed are reached.

A non-exhaustive list of parameters influencing repair is provided in this section. Some of these parameters are also relevant for reuse and upgrade of products.

7.2.1 Disassembly sequence

In general, the disassembly sequence is the order of steps needed to remove a part from a product. The disassembly sequence depth is the number of minimum steps required to remove a part from a product.

The analysis of disassembly sequences and depths is fundamental to facilitate the disassembly of priority parts from products, although other design parameters can also be important (see below).

Annex B includes more details about disassembly sequence and disassembly sequence depth.

7.2.2 Fasteners type, number and visibility

Fasteners and connectors play an important role in the disassembly of a product, as replaceable parts in a product are affixed in a product and while accessing a priority part most likely a number of fasteners need to be opened and closed. Fasteners are closely interlinked to the assessment of necessary tools and skills for RRU. The number of fasteners and their visibility can be a proxy for the time needed to repair or upgrade a product.

7.2.3 Tools needed

Tools, in most cases are indispensable for carrying out the repair, upgrade or preparation for re-use process. In some cases they are also necessary for testing after repair or for diagnostics.

They vary in availability and complexity and/or cost. They can be of general purpose or be dedicated to certain products.

7.2.4 Disassemblability

WORKING NOTE: CHANGES ARE FORESEEN TO BE IN LINE WITH THE WORK ON JTC10/WG4

The disassemblability of products is influenced, among other technical aspects, by the number of steps needed to disassemble parts of the product, by the ease of access to parts and by the difficulty of the operation itself. These parameters can be used to assess the ability of a product to be disassembled in order to have access to priority parts. Additionally, these parameters can be combined into single indices. Annex B includes alternative methods for the quantification of such indices (from easier and practical to more complex).

Note: Either the use of quantitative methods, the individual assessment of single parameters, or both, can be considered appropriated to assess the disassemblability of the product under study.

7.2.5 Working environment

Working environment requirements refer to the degree of specialisation of the environment required to perform the RRU process; which can take place for example at home, in a professional workshop or in a production environment. Security provisions and equipment are some of the factors influencing where the RRU process can be performed.

7.2.6 Skill level

Repairing a faulty product requires a certain technical skill of the person who performs the repair. This comprises the ability to identify and localise the fault, to access the faulty part within the product, handle the tools safely and in case of electrical and electronic products to manage risks due to electricity and static discharge.

7.3 Assessment of manufacturer support to facilitate repair, reuse or upgrade

Depending on the type of product the repair, reuse or upgrade process might require technical competences and/or access to certain information, which can be dependent on a professional status. The necessary level of skills depends on the product and is closely associated to the identification of priority parts.

Next to the assessment of the product or design-related aspects of the product, the support provided by manufacturers to faciliate repair, reuse or upgrade shall be assessed based on the declaration of the manufacturer.

7.3.1 Diagnostic support and interfaces

This step of the assessment of product service support is about the provision of information facilitating the identification of the problem or faulty component. Further it relates to the type of interface available for a repair, upgrade or preparation for re-use process, including operations such as adjustment or resetting of parameters or settings.

Depending on the product group this information might be made available through self-diagnostic capabilities of the product or it might be made otherwise available by the manufacturer.

Technical Committees developing product specific standards, defining methods for assessing the ability to repair, upgrade or re-use, shall establish for their product group a categorisation of tools for diagnostic support and interfaces.

The product interface category of a product and or the support provided by a manufacturer can be calculated for example according to Annex B.

7.3.2 Availability of spare parts, software and firmware

The availability of spare parts is a crucial aspect of the repairability of a product, as the availability of functioning replacement parts for faulty or worn-out parts is a prerequisite for a successful repair. For many product groups, the availability of software and firmware is comparably relevant.

Spare parts availability could refer to a specified minimum number of years after the sale of the product, or the end of last production, during which spare parts will be available or to an exact date till which after sales support will be provided for the product or priority part.

7.3.3 Information availability

Availability of Information is an essential ingredient for enabling repair, reuse and upgrading of products. Information availability should be assessed with regard to the audience (target group) of information, communication channels, formats and types of information.

The level of detail of this information will largely vary on the targeted audience. Information can be freely accessed by the public or provided to users when the product is purchased (unrestricted access), or provided specifically to interested third parties by registration or similar (restricted access).

Information mechanisms include amongst others, websites, instruction manuals / handbooks, user manuals or information on the product or its parts (e.g. warnings).

7.3.4 Information types

For the assessment of the information the following types should be considered. For a meaningful assessment, the types and availability of information should be matched with the skills level, representing specific target audiences. The list is non-exhaustive and may be extended to cover product-group specific aspects.

- Product identification and documentation
- List of spare parts and how to obtain them
- Overview of repair services offered by the manufacturer
- Information about upgradability of the product
- Disassembly and repair instructions including identifying required tools
- Troubleshooting instructions such as software diagnostic tools or testing hard and software
- Repair training material for professionals

A proposal for a more detailed method for how information availability can be categorised can be found in Annex B.

7.4 Reusability and upgradability

Re-use assumes that the product is fully functional when transferred to another user. Hence, in addition to the parameters provided in section 7.2 and 7.3 relevance of additional parameters shall be assessed for reusability and upgradability.

7.4.1 Reusability

The Reusability of a product is predominantly influenced by its ability to withstand wear and tear during product use. As such data points from standard (prEN45552) indicating the durability of a product shall be taken into consideration. Depending on the product category, built-in functionality for supporting transfer of data from the old to the new product can be a key factor that determines whether products are being reused in practice. The same importance should be given to secure data deletion where needed to support the deletion of all data contained in data storage components (i.e. hard drives and solid state drives) in order to grant the security of personal data and to facilitate the reuse of the product or data containing components.

A proposal for a more detailed method for how information availability can be categorised can be found in Annex B.

7.4.2 Upgradability

Upgradability of the product can be assessed by measuring the possibility to upgrade one or more product-specific key features by means of replacing hardware or software components. For assessing the upgradability of products the process in chapter 7.2 and 7.2 should be followed. Specific attention however should be given to the role of software and firmware. The ability to upgrade a product might have a positive impact on the likelihood that a product is being reused.

A proposal for a more detailed method for how information availability can be categorised can be found in Annex B.

Annex A
(normative)

Common General Purpose Tools

This annex contains a list of commonly available tools and their reference standards in table A.1

This list represents the tools most commonly used for repair purposes in general, regardless of the specific product being repaired.

As a means of identifying the lowest possible threshold for those processes which cannot be performed without the use of any tools, it contains a very limited number of tools which are hand operated, widely used and readily available for purchase by any individual or business without restrictions.

NOTE 1: Many processes, such as the removal of fasteners for instance, can be completed with several different types of tools. This annex lists only the simplest tool that can be used to complete a given process. Although many other types of tools may be used in practice during a given repair, upgrade or preparation for re-use process, only the ability to use the simplest version of the tool as listed in this annex determines whether the process is categorised as requiring general-purpose tools.

EXAMPLE 1: Screws may be actuated by a regular screwdriver or by an electrically or pneumatically powered driver equipped with the appropriate driving bit. Since only hand operated tools are considered as common general-purpose tools, only the regular screwdriver is listed here. Any process which is not feasible with a regular screwdriver but requires the use of a power tool, for instance due to the required level of fastening torque, is therefore not categorised as requiring general-purpose tools.

EXAMPLE 2: A hexagon head bolt may be turned with a variety of tools such as an open-ended wrench, box wrench, combination wrench, socket wrench, adjustable wrench etc. Since the combination wrench can be considered to be the simplest and most universal of these tools, only the combination wrench is listed here. Any process which is not feasible with a combination wrench but for instance requires the use of a socket wrench due to the fact that the fastener is deeply recessed, is therefore not categorised as requiring general-purpose tools.

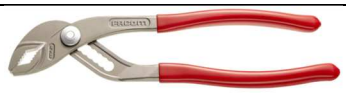
EXAMPLE 3: Both regular and spherical head hex keys may be used on hex socket head bolts. Since the regular hex key can be considered to be the simplest and most universal of these tools, only the regular hex key is listed here. Any process which is not feasible with a regular hex key but requires the use of a spherical head hex key, for instance because access is restricted and the fastener needs to be accessed at an angle, is therefore not categorised as requiring general-purpose tools.

NOTE 2: Most tools come in different sizes. This list only refers to the tool type. Although some sizes are more common than others, for practical purposes, any size of the listed tools is considered to be a common general purpose tool.

NOTE 3: Personal safety equipment and cleaning tools are not included in this list.

Table 1 – Exhaustive list of commonly available tools and their reference standards

Tool type	Illustration (informative example)	Reference
Hammer, steel head		ISO15601

Combination pliers		ISO5746
Half-round nose pliers		ISO5745
Multigrip pliers (multiple slip joint pliers)		ISO8976
Diagonal cutters		ISO5749
Combination pliers for wire stripping & terminal crimping		
Combination wrench		ISO7738
Hexagon socket keys (Allen keys)		ISO2936
Screwdriver for slotted heads		ISO2380
Screwdrivers for cross-recessed (Phillips® and Pozidriv®) heads		ISO8764
Screwdrivers for hexalobular recess (Torx®) heads		ISO10664 (driving feature)
Multimeter		
Utility knife (cutter) with snap-off blades		

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Annex B
(informative)

Assessment methods for RRU

This annex provides more detailed information on parameters and methods of the framework. It offers a toolbox to choose from, as needed for the development of product specific standards. Parameters and methods included in this annex can be grouped in three main assessment options:

1. Qualitative assessment, i.e. evaluating the existence of specific attributes associated to the product
2. Semi-quantitative assessment, i.e. individual or combined quantification of quality levels of one or more attributes associated to the product
3. Quantitative assessment, i.e. numeric measuring of the degree to which an attribute is addressed in the product (e.g. indices)

Qualitative assessment is suitable for the development of product specific checklists of requirements, although differentiation between products could be limited. Semi-quantitative and quantitative assessment in contrast can allow for a more comprehensive assessment although at the expense of more complexity and uncertainty.

B.1 Qualitative assessment

The aim of qualitative assessment is to develop a product-specific checklist of positive attributes that can positively influence the reparability, reusability and upgradability of the product.

This can be based on the analysis of the general parameters described in chapter 7, although attributes can be either adapted to the targeted product group, removed (when not relevant), or introduced (if new. parameters are identified).

Table 2 - Example of a check-list of positive attributes positively influencing the upgradability of an illustrative product group

Parameter	Positive aspect
Modular design	The product has a modular design facilitating the change of priority parts (to be defined for the specific product group)
Updatable features	The product allows users the possibility to update all product-specific key features (to be defined for the specific product group) with no limitation of time. The update of feature shall be achievable in the product without performing a product exchange. For institutional products, ports, slots, or connectors used for the update are accessible either with (a) no tools, or (b) common tools, or (c) tools provided by or available from the manufacturer. For all other products, ports, slots, or connectors are accessible without tools. Information is provided about: a. Features being claimed and communication to consumers

	b. Update method, including a list of required tools, for each feature claimed c. Documentation that these are offered for at least XX years after the point of sale
Availability of spare parts	Original or backwardly compatible spare parts are widely available to replace priority parts (to be defined for the specific product group) Availability is ensured for a minimum of X years following the end of production for the model
Types of tools needed	Basic tools (like scissors, flathead and screwdrivers) are needed to disassemble priority parts
Data deletion	Built-in secure data deletion functionality is available to support the deletion of all data contained in data storage parts (i.e. hard drives and solid state drives) in function of the risks faced and in order to grant the security of personal data and to facilitate the reuse of these parts.

B.2 Semi-quantitative assessment

A semi-quantitative assessment enables the evaluation of the quality of products in relation to one or more RRU parameters of relevance.

This can be performed following these steps:

1. Determination of priority parts for the assessment
2. Selection of one or more parameters of relevance for a target product group
3. Assignment of a ranking/classification score to each parameter based on evaluation criteria

The higher the score the better the RRU associated with that parameter. Scores of single parameters can also be normalised, weighted and aggregated into a single rating score or thematic indices (e.g. design characteristics and service conditions). The rating can be expressed for instance on a 1-to-5 scale, on 1 0-to-1 scale, or using a different basis.

Note: Weights can be assigned if some criteria are considered to be more important (e.g. to highlight objective or subjective attributes, or to focus on specific aspects).

Technical Committees developing product specific standards for assessing the ability to repair, upgrade or re-use products, should carefully select parameters and decide on classification criteria and aggregation. TCs should integrate this work with the assessment of priority parts.

Further guidance for the evaluation and rating of the parameters reported in Section 7 is provided in the following.

B.2.1 Disassembly sequence

The analysis of disassembly sequences is fundamental to facilitate the disassembly of priority parts from products, some aspects to take into consideration when describing the disassembly sequence are:

1. Priority parts can be labelled in the progressive removal order.
2. Different strategies to disassemble a part from products can be compared in terms of disassembly steps.
3. Optimal disassembly sequences can be for instance found through process simulation or on through the analysis of their relative accessibility and importance.

The disassembly sequence depth is the number of minimum steps required to remove a part from a product and it is obtained by applying an iteration of steps:

- Step1: Every part that can be removed are set at Level 1 and a list of remaining parts is made
- Step2: Every part that can be removed are set at Level +1 and a list of remaining parts is made
- Step3: Go back to Step2.

Knowing the largest sequence depth of a product, a score could be assigned to this parameter for each priority part according to the following formula:

$$S_{disassembly\_steps,i} = 1 - \frac{DD_i}{DD_{Max}}$$

Where:

DD_i is the sequence depth for the part i

DD_{max} is the longest sequence depth for the product group

B.2.2 Fasteners

Type, number and visibility of fasteners could be assessed as follows. The assessment shall be done for each priority part and the results shall be summed up to an overall score.

Score for the type of fasteners (SFT):

1. Only screws and/or clear multiple-use snap-fits are used to assemble priority parts (1 point)
2. Multiple-use snap fits and/or stay-sticky glue fasteners are used to assemble priority parts (0.5 points)
3. Adhesives, single-use snap fits and/or solders are used to assemble priority parts (0 points)

Score for the visibility of fasteners (SVF):

1. Screws and other fasteners used to assemble priority parts are clearly visible (1 point)
2. Screws and other fasteners used to assemble some parts are not clearly visible (0.5 points)
3. Screws and other fasteners used to assemble priority parts are hidden, e.g. behind an adhesive or other parts (0 points)

B.2.3 Tools

The tools required for a RRU process could be categorised as in the table below.

Table 3 – Tool availability categories and proposal for corresponding scores

Category	Description	Score
Toolless	A RRU process, which can be carried out without the use of any tools	4
Common general purpose tools	A RRU process which can be carried out using only common general purpose tools (including the generic tools listed in Annex A)	3
Professional product group specific tools	A RRU process which can be carried out only a. with a tool that is supplied with the product, part, accessory, consumable or fastener, or b. with a product group specific set of tools.	2

	Note: i) Product-specific TCs shall establish a set of specific tools relevant for their product group. ii) The list must meet the following conditions: 1. it covers parts, consumables, accessories and fasteners 2. Only non-proprietary tools are listed. A tool is considered to be non-proprietary if it is legally available for purchase by the general public and if any applicable patents are available for licensing under fair, reasonable, and non-discriminatory terms. 3. Only tools are listed which are required for repairing, upgrading or preparing for re-use a significant part of products produced by at least two different manufacturers. iii) The list must be periodically updated to follow the pace of development in the RRU sector for their product group. iv) Alternatively, TCs could further develop and detail the above set of criteria that allows to define and verify professional, product group specific tools. This should better allow to add novel tools and avoid limiting innovation. v) Ideally a listed basic set of professional, product group specific tools could be combined with criteria to complement the list. vi) In the absence of any list or criteria of professional, product group specific tools defined in a product-specific standard, the category 'professional, product group specific tools' is limited to tools supplied with the product.	
Proprietary tools	A RRU process which can be carried out only with proprietary or very specialised tools available to the manufacturer or its repair service providers. Note: TCs should not closed lists for this category of tools.	1

$$S_{tool,i} = \frac{Tool\ availability_i}{Tool\ availabilty_{Max}}$$

Where

- $S_{tool,\,i}$: the tool score for priority part i
- Tool availability $_i$: the tool score for priority part i
- Tool availability $_{max}$: the maximum tool score achievable

B.2.4 Disassemblability

An overall score for disassemblability of the priority part i could be assessed either as combination of the above scores related to product design parameters or using one of the quantification methods reported later. In the latter case, the overall score for disassemblability would be calculated as follows:

$$S_{disassemblability,i} = 1 - \frac{DS_i}{DS_{Max}}$$

Where

- $S_{disassemblability, i}$: the disassemblability score for the priority part i
- DS_i: the quantitative value of the parameter used to assess the disassemblability of the priority part *i* (e.g. disassembly index, time for disassembly)
- DS_{max}: the maximum value of the parameter used to assess the disassemblability of the product group (e.g. disassembly index, time for disassembly)

B.2.5 Working environment

The environment can be categorised according to the table below.

Table 4 - Working environment categories and proposal for corresponding scores

Category	Description	Score
Home / no requirements	If a repair, upgrade or preparation for re-use process can be carried out without any working environment requirements it is categorized under home / no requirements.	4
General purpose workshop	If a repair needs to be carried out in a basic workshop with the common equipment listed in Annex A, that process is categorised as requiring a general-purpose workshop. It could be field interventions are typical for certain repairs. If field interventions are done with the common equipment listed in Annex A, those field interventions are classified as processes requiring a general-purpose workshop. The list of workshop equipment in Annex A is intended to represent the equipment most commonly found in repair workshops in general, regardless of the specific product being repaired. As a means of identifying the lowest possible threshold for those processes which cannot be performed in the home environment, it contains a very limited set of equipment which is widely used and readily available for purchase by any individual or business without restrictions.	3
Specialised workshop	If a repair, upgrade or preparation for reuse process cannot be carried out - in a home environment - or in a basic workshop with the equipment listed in Annex A but can only be carried out in a specialised workshop with a special set of equipment, that process is categorised as requiring a specialised workshop. Technical Committees developing product specific standards, defining methods for assessing the ability to repair, upgrade or re-use, shall establish for their product group a	2

	list of specialised workshop equipment, relevant for repair, reuse and/or upgrade. Depending upon the product group, a finite list of specialised workshop equipment could be developed in a product specific standard defining methods for assessing the ability to repair, upgrade or prepare for re-use. The list would meets the following conditions: - Only non-proprietary equipment is listed. Equipment is considered to be non-proprietary if it is legally available for purchase by the general public and if any applicable patents are available for licensing under fair, reasonable, and non-discriminatory terms. - Only equipment is listed which are required for repairing, upgrading or preparing for re-use a significant part of products produced by at least two different manufacturers. Alternatively to a finite list TCs could further develop and detail the above set of criteria that allows to define and verify specialised workshop equipment. This should better allow to add novel tools and avoid limiting innovation. In the absence of a finite list of professional, product group specific tools defined in a product-specific standard defining methods for assessing the ability to repair, upgrade or prepare for re-use a given category of products, the category 'specialised workshop' is void.	
Production environment	If a repair, upgrade or preparation for re-use process cannot be carried out in any of the aforementioned environments, or if there are safety or information security provisions that mean that it can only be carried out in an environment that is comparable with the environment in which the product is manufactured, that process is categorized as requiring a production site environment. TCs should not make criteria for this category of working environment	1

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717 $$\frac{Working\ environment_i}{Working\ environment_{Max}}$$

718 Where:

- $S_{setting,\ i}$: the setting score for priority part i
- Working environment $_i$: the setting score for priority part i
- Working environment $_{max}$: the maximum setting score achievable

B.2.6 Skill level

The skill categories a given process can be classified as shown in the Table below.

Table 5- Skill categories and proposal for corresponding scores

Category	Description	Score
Layman	An example of a layman is a consumer able to repair or upgrade their own products in a household environment with readily available tools.	4
Generalist	Independent professional services or non-profit repair initiatives where a generalist with knowledge of basic techniques and safety precautions is able to carry out repairs or upgrades in a workshop with specialised tools.	3
Professional	Independent or manufacturer authorised professional services centre where individuals have training and/or experience for the specific product with dedicated tools to do the repairs. An authorised professional is a professional who is recognized by the manufacturer and receives from the manufacturer any tools, information or other support required for the type of repair that he or she is entrusted with by the manufacturer, including tools, information or other support not available to the general public or independent repair professionals.	2
Manufacturer	Professional repairer as in level 3 with full access to all design documentation and maintenance files of products, working in the manufacturer's workshop. In some instances, certain repair operations may be restricted on grounds of safety, quality, performance or data security to a limited group of companies that have a closer relationship to the manufacturer and can be directly trained and audited.	1

$$S_{skill,i} = \frac{Skill_i}{Skill_{Max}}$$

Where:

- $S_{skill,\ i}$: the skill score for priority part i
- Skill $_i$: the skill score for priority part i
- Skill $_{max}$: the maximum skill score achievable

B.2.7 Diagnostic support and interface – categories and formula

Interfaces for diagnostic support, failure detection, software and firmware updates, resetting of failure modes and factory settings can be categorised as follows:

Examples of different diagnostic interfaces include

- **Visually intuitive interface:** If a repair, upgrade or preparation for re-use process can be carried out by just a visual interface that can be intuitively understood without the need for any supporting documentation or software, that process is categorised as having a visually intuitive interface.
- **Coded interface with public reference table:** If a repair, upgrade or preparation for re-use process only can be carried out with supporting documentation or software, and through reading and/or entering codes which are available in a table, which is supplied with the product and / or publically available, that process is categorised as having a coded interface with public reference table.
- **Publically available hardware / software interface**: If a repair, upgrade or preparation for re-use process can only be carried out through the use of hardware and software which is publically available, that process is categorised as having a publically available hardware / software interface.
  This can include hardware functionality testing software tools developed by a third party, provided the software tools are publicly available and the manufacturer provides information on their accessibility and applicable updates. The product has to be equipped with an appropriate interface for hardware and software to do fault diagnosis and reading, adjustment or resetting of parameters or settings (e.g., external memory device; data cable connection; or from a remote source using a network connection). The port, slot, or connector that is used for the hardware and software interface is accessible without tools.
- **Proprietary interface**: If a repair, upgrade or preparation for re-use process can only be carried out using proprietary tools for diagnosis, change of settings or transfer of software, that process is categorised as having a proprietary interface.

Table 6 - Interface intensity categories for parts and proposals for corresponding scores

Category Description	Score
Visually intuitive interface	4
Coded interface with public reference table	3
Publically available hardware / software interface	2
Proprietary interface	1

$$S_{interface,i} = \frac{Interface\ intensity_i}{Interface\ intensity_{Max}}$$

Where:

- $S_{interface,\ i}$: the interface score for priority part i
- Interface intensity i: the interface score for priority part i
- Interface intensity max: the maximum interface score achievable

A design that allows with a more accessible diagnostic's and reset interface, will enable for a broader range for RRU scenarios.

B.2.8 Detailed method to determine a score for availability of RRU parts, software and firmware

The availability of spare parts and parts for upgrading as such and their availability over time may be assessed according to the following table. The availability of software and firmware updates may be assessed the same way as for parts.

TCs should specify duration that is to be considered as short, mid or long term, taking the maximum known lifespan of products covered as a reference for long-term availability and minimal legal requirements on consumer guarantees as a reference for short-term availability

Table 7 - Spare parts availability categories for parts and proposal for corresponding scores

Category Description	Spare parts availability score
Long-term availability	4
Mid-term availability	3
Short-term availability	2
No information on duration of availability	1
Spare part not available	0

$$S_{spare,i} = \frac{Spare\ part\ availability_i}{Spare\ part\ availability_{Max}} * C_i$$

Where:

- $S_{spare,\,i}$: the spare parts score for priority part i
- Spare part availability $_i$: the spare parts availability for priority part i
- Spare part availability $_{max}$: the maximum spare parts availability achievable
- C_i: correction factor if spare parts for part i are only available to specific service condition target groups ($0 \leq C_i \leq 1$)

If a spare part is not required to do a repair of part i, the spare parts score for priority part i ($S_{spare,\,i}$) is one by default.

If upgrade or spare parts are only available to specific service condition target groups (e.g. professional or authorised repairers), a correction factor (C_i) should be applied. TCs should decide on the purchaser groups and correction factors to be assigned.

B.2.9 Method to determine availability of RRU information

Information availability may be assessed based on the types of information available. Classification of types of information into categories below needs to be product group specific. As an alternative or in addition the degree of availability itself could be categorized based on how accessible the information is.

Table 8 - Information availability categories and proposal for corresponding scores

Category Description	Information availability score
No information available	0

Basic information available	2
Comprehensive information available	4

$$S_{info,i} = \frac{Information\ availability_i}{Information\ availability_{Max}} * C_i$$

Where:

- $S_{info,i}$: the information score for priority part i
- Information availability $_i$: the information availability for priority part i
- Information availability $_{max}$: the maximum information availability achievable
- C_i: correction factor if information for part i are only available to specific service condition target groups ($0 \leq C_i \leq 1$)

It is possible information availability is better evaluated at product (or assembly) level. In such case the information availability score for all priority parts covered is one.

If information is only available to specific service condition target groups (e.g. professional or authorised repairers), a correction factor (C_i) shall be applied. TCs should decide on the purchaser groups and correction factors to be assigned.

Availability of information facilitates repair, reuse and upgrade operations. Service support with most information available receives the highest score.

B.2.10 Reusability and upgradability

B.2.10.1 Availability of upgradable features

The score for the availability of updatable features (S_{UF}) could be assessed as follows:

1. The product allows users the possibility to upgrade one or more product-specific key features with no limitation of time. The update of feature shall be achievable in the product without performing a product exchange (1 point)
2. The product allows users the possibility to upgrade some product-specific key features only for a limited period of time (e.g. after XX years new updates will not be supported by the model) (0.5 points)
3. The product does not allow users the possibility to update features (0 points)

B.2.10.2 Reusability

In addition to data points from standard prEN45552 indicating the durability of the product and its components, a score for data deletion (S_{DD}) could be assessed as follows:

1. Built-in secure data transfer and deletion functionality is available to support the deletion of all data contained in data storage parts (i.e. hard drives and solid state drives) in function of the risks faced and in order to grant the security of personal data and to facilitate the reuse of these parts (1 point)
2. Secure data transfer and deletion is available under request to support the deletion of all data contained in data storage parts (i.e. hard drives and solid state drives) in function of the risks faced and in order to grant the security of personal data and to facilitate the reuse of these parts (0.5 points)
3. Secure data transfer and deletion is not available (0 points)

B.2.11 Scoring RRU based on repair setting and service conditions

RRU for a product (or any priority part) can be classified according to repair situation (tools, skills, service environment) and service conditions (availability of spare parts and of information available product interface

and software support). A score can be given to evaluate the RRU from a technical point of view, in a semi-quantitative way, according to the following formula:

$$Score_{Rep,Reuse,Upgr} = \left[\sum_{i=1}^{i=p} W_{Need,i} * S_{tool,i} + \sum_{i=1}^{i=p} W_{Need,i} * S_{setting,i} + \sum_{i=1}^{i=p} W_{Need,i} * S_{skill,i} + \sum_{i=1}^{i=p} W_{Need,i} * S_{interface,i} + \sum_{i=1}^{i=p} W_{Need,i} * S_{spare,i} + \sum_{i=1}^{i=p} W_{Need,i} * S_{upgr,i} + \sum_{i=1}^{i=p} W_{Need,i} * S_{softw,i} + \sum_{i=1}^{i=p} W_{Need,i} * S_{info,i} + \sum_{i=1}^{i=p} W_{Need,i} * S_{fastener,i}\right]$$

Where:

- $W_{need,\,i}$: the overall weighting factor of part i
- $S_{tool,\,i}$: the tool score for priority part i
- $S_{setting,\,i}$: the setting score for priority part i
- $S_{skill,\,i}$: the skill score for priority part i
- $S_{interface,\,i}$: the interface score for priority part i
- $S_{spare,\,i}$: the spare parts score for priority part i
- $S_{upgr,\,i}$: the upgrades score for priority part i
- $S_{softw,\,i}$: the software score for priority part i
- $S_{info,\,i}$: the information score for priority part i
- $S_{fasten,i}$: the fastener score for priority part i

Tables are given in this chapter for S_{tool}; $S_{setting,}$; S_{skill}; $S_{interface}$; S_{spare}; S_{upgr}; S_{softw}; S_{info} and $S_{fastner}$. The higher the score the better the RRU of the part or product, the formula normalises the scores to one. A score of zero represents a product for which RRU is not an option, a score of one represents a product with ideal RRU.

The formula presented here is the most comprehensive approach possible. Assessment of tools for repair, reuse and upgradability should be done separately ($Score_{Rep}$; $Score_{Reuse}$; $Score_{Upgr}$). TCs could decide to omit weighting, leave out certain aspects (e.g. because they are irrelevant for their product group).

This scoring system could be the basis for product classification and requirements. Optionally at TC could choose to complement those with minimum sub-scores on specific criteria (e.g. $S_{info,\,i}$ shall be at least XY).

For example, if 'professional repair by an independent repairer' needs to be assessed, S_{tool}; $S_{setting,}$; and S_{skill} could be omitted from the formula. The product design should have minimum scores for S_{tool}; $S_{setting,}$; and S_{skill} corresponding to a repair situation for 'independent repairer'.

Ranking products (or parts) in terms of a RRU score makes sense. But, it can be important to take into account the need for disassembly in terms of functional criticality, value, environmental impact and/or failure rate of the parts. This can be expressed by an overall need for disassembly weighting factor W_{need}. This overall weighting factor is a function of the functional criticality (w_{crit}), value (w_{value}), environmental impact (w_{env}) and/or failure rate (w_{fail}).

Technical Committees developing product specific standards, defining methods for assessing the ability to repair, upgrade or re-use, should carefully decide on classification of required tools, skills and service environment, as well as the service conditions the (available product interface and firmware updates; availability of spare parts and of information needed to carry out the repai). TC should integrate this work with the assessment of priority parts.

B.3 Quantitative assessment

B.3.1 Disassemblability

B.3.1.1 Disassemblability index

A disassembly index can be calculated based on the number of parts to be removed, the fastener types and difficulty coefficients.

Using the minimum number of fasteners is a key principle in design for disassembly. Different fastener types may indeed require different unfastening tools, different access directions and different disassembly configurations, which would ultimately result in an increase in the disassembly effort.

The parameter is calculated with the following equation:

$$dd = dd_n + \beta \cdot dd_f = \frac{1 + n_D}{n} + \beta \cdot \frac{\sum_{k=1}^{h} \propto_k \cdot f_{Dk}}{f}$$

Where:

- dd is the disassembly index of a part
- $(1 + n_D)$ is the number of all the parts to be removed (including the part whose disassembly index is being evaluated),
- n is the total number of parts,
- h is the number of fastener types
- f_{Dk} is the number of fasteners of the k^{th} type to be removed,
- f is the total number of fasteners in the system,
- α_k is the difficulty of disassembling a k^{th} type fastener (Allowing for values of the coefficients α_k in the interval [0, 1], $\alpha_k = 1$ indicates the maximum difficulty of disassembly),
- β is a coefficient (β > 1) which takes into account the greater weight of the second term dd_f with respect to the first dd_n.

The disassembly index can assume values from 0 to 1+β, with the maximum value expressing the maximum disassembly depth. This occurs when, in order to remove a part, it is necessary to disassemble all the fasteners and all the other parts present in the system. The α and β coefficients which need to be quantified for the analysed product based on other methods (e.g. the disassembly time).

B.3.1.2 Time for disassembly

The disassemblability of products is influenced, among other technical aspects, by the number of steps needed to disassemble parts of the product, by the ease of access to parts and by the difficulty of the operation itself. The time for disassembly can be an aggregated parameter to assess the overall disassemblability of products. Time can easily measured but the overall length depends on the operator skills and other factors. The Ease of Disassembly Metric (eDiM)1 method is based on the Maynard Operation Sequence Technique (MOST)2 and

[1] Vanegas P. et al. (2016) Study for a method to assess the ease of disassembly of electrical and electronic equipment. JRC Technical Reports.

[2] MOST is a measurement technique used by industrial engineers and practitioners to measure assembly times for a wide variety of products. Reference values of eDIM have been determined by using it.

requires information about product parts and adopted fasteners that can be directly verified within the product.The eDiM is a comprehensive method, although it comes with a significant computational effort.

The tasks necessary to disassemble a particular part/product are listed in eDiM and reference time values are associated to each of them, representing the effort needed to perform such operation. The eDiM report includes a database of common disassembly tasks which can be adapted, extended and/or updated.

The overall eDiM, measured in time units, is calculated by summing all contributions associated to a determined disassembly sequence. Subjectivity is reduced when single disassembly activities are measured and standard values quantified, as done in MOST.

As shown in Figure 1, a spreadsheet can be used to calculate the eDiM. The first five columns of the table contain the data required to compute the time taken to complete the six categories of disassembly tasks:

1. Parts are listed in Column 1 in the order of disassembly. If parts are attached by different connectors, they can be repeated in the column.
2. Connector types used are listed in Column 2 in the order in which they should be unfastened to remove the different parts. An example is provided in table 10 to show different connector types and their main characteristics.
3. The number of connectors of the same type in a part are specified in Column 3.
4. The number of any manipulations needed to access a connector are listed in Column 4. This could for instance be the case of a product that has to be turned upside down to remove the connector.
5. Information on the ease of identification of the connector is contained in Column 5. Two categories, visible and hidden, are presented in table 10.
6. The type of tool required for disconnecting the fasteners is listed in Column 6. Tools can be selected from a predefined list. The box is left empty if no tool is required.

The time needed for the disassembly process is estimated through the last seven columns based on the information provided in the first six columns and the MOST reference time values.

7. Column 7 indicates the time needed to change tools defined in column 6. This is calculated based on the information on connectors provided in MOST, from which it can be determined whether a tool is required for disconnecting that type of connector.
8. Column 8 indicates the time needed to identify connectors. This is calculated using the information provided in Column 5 and the reference time values.
9. Column 9 indicates the time needed for product manipulation. This is calculated using the number of manipulations reported in Column 4 and the reference time values.
10. Column 10 indicates the time needed for positioning tools, in relation to the type of connectors used. This is calculated by multiplying the connectors specified in Column 3 by the reference time values for tool positioning.
11. Column 11 indicates the time needed for disconnecting the fasteners. This is calculated by multiplying the fasteners indicated in Column 3 by the reference time values for disconnecting the corresponding type of fastener.
12. Column 12 indicates the time needed for removing parts. This is calculated once per part.
13. The overall eDIM for a set of parts is assessed in Column 13 as sum of time values reported in columns 7 to 12.

The eDiM method is presented here as a method to estimate the time for disassembly, however the method could be used as well to estimate the time for reassembly, the sum of the two would allow the estimation of the total time needed for replacing one or more parts.

Figure 1– Generic eDiM calculation sheet for N parts

1	2	3	4	5	6	7	8	9	10	11	12	13
Disassembly sequence of components	Disassembly sequence of connectors of components	Number of connectors	Number of product Manipulations	Identifiability (0,1)	Tool Type	Tool Change (s)	Identifying (s)	Manipulation (s)	Positioning (s)	Disconnection (s)	Removing (s)	eDIM (s)
1...												
2...												
...												
...												
...												
N												

941

942 **Table 9 – Proposed MOST sequences for the disconnection of fasteners**

Connectors	Connector characteristics	Tool	MOST sequence	TMU	Time (s)
Screw	Length < 2 X diameter (D)				
Type 1	Screw D <= 6 mm	Power tool	|L3|	30	1.1
Type 2	Screw 6 mm < D < 25mm	Power tool	|L6|	60	2.2
Type 3	Screw D <= 6 mm	Screwdriver	|L10|	100	3.6
Snapfit					
Type 1	Force < 5 N	Hand	|L1|	10	0.4
Type 2	5 < Force < 20 N	Screwdriver	|L3|	30	1.1
Type 3	20 N < Force	Screwdriver	|L6|	60	2.2
Hinge					
Type 1	Force <5 N	Hand	|L1|	10	0.4
Type 2	5 N < Force < 20 N	Hand	|L3|	30	1.1
Type 3	20 N < Force	Hand	|L6|	60	2.2
Cable Plug					
Type1	Force < 5 N	Hand	|L1|	10	0.4
Type2	5 N < Force < 20 N	Hand	|L3|	30	1.1
Type3	20 N < Force	Hand	|L6|	60	2.2
Clamp					
Type1	Force < 5 N	Hand	|L1|	10	0.4
Type2	5 N < Force < 20 N	Hand	|L3|	30	1.1
Type3	20 N < Force	Screwdriver	|L6|	60	2.2
Tape					
Type1	Force < 5 N	Hand	|L1|	10	0.4
Type2	5 N < Force < 20 N	Hand	|L3|	30	1.1
Type3	20 N < Force	Hand	|L6|	60	2.2

943

944 **Table 10 - Example of table of reference values (time) for standard disassembly tasks based on MOST**
945 **sequences**

Disassembly task	Description	Sequence	TMU	Time (s/task)
Tool Change	Fetch and Put back	|A1B0G1|+|A1B0P1|	40	1.4
Identifying	Localising connectors			
	Visible are > 0.05 mm^2			0
	Hidden: visible are < 0.05 mm^2	|T10|	100	3.6
Manipulation	Product handling to access fasteners	|A1B0G1|+|L3 |	50	1.8
Positioning	Positioning tool onto fastener	|A1B0P3A0|	40	1.4
Removing	Removing separated components	|A1B0G1| + |A1B0P1|	40	1.4

946

947 ### B.3.2 Product reparability index

948 Product reparability is determined by proper design parameters (e.g. skills, tools needed) and the availability of
949 service conditions (e.g. availability of spare parts and information). The range of repairs that can be done by
950 professionally skilled individuals in a specialised setting is distinctly different to those that can be implemented
951 by consumers in a home environment.

952 So, TCs that wish to develop a method to determine a product reparability index should establish what
953 prerequisites are to proceed with the calculation of a product reparability index, and how a manufacturer shall
954 document these. They shall use the classification of required tools, skills and service environment and service
955 conditions (available product interface and firmware updates; availability of spare parts and of information
956 needed to carry out the repair) developed according to section B.1.

957 The Product reparability index can be expressed as the combination of the portion of the product parts that
958 could be repaired and the time needed to do the repairs:

959 $$R_{repair} = \sum_{i=1}^{p} \frac{t_{repair,i}}{m_i * W_{need,i}} * \frac{m_{tot}}{t_{ref}}$$ $R_{repair} \geq 0$; [dimensionless]

960 where:

961 - R_{repair} = Product reparability index [dimensionless];
962 - p = number of parts considered [dimensionless];
963 - m_i = mass of part i [kg];
964 - $W_{need,i}$ = overall weighting factor of part i, [dimensionless];
965 - $t_{repair,i}$ = Time for repair of part i [s];
966 - t_{ref} = reference time [s];
967 - m_{tot} = total mass of the product [kg].

968 The more parts that can be repaired and the shorter the repair time for those parts, the lower the index, the
969 better the reparability. A normalisation is done by dividing by a reference time (t_{ref}). A place holder for weighting
970 need for reparability of parts (e.g. $W_{need,i} = w_{fail,i} * w_{crit,i} * w_{env,i} * w_{value,i}$) is included in the formula. Any
971 weighting shall be done with the method developed according to section 6.

Alternatively to total mass of the product (m_{tot}) and mass of part i (m_i), number of parts (n_{tot}) could be used in the formula.

Time for repair of a priority part ($t_{repair,i}$) is the sum of the time needed to do disassembly and reassembly, as well as time needed to do any repair and testing of the proper functioning of the part:

$$t_{repair,i} = t_{dis,i} + t_{test,i} + t_{reass,i} \quad [s]$$

where:

- $t_{dis,i}$ = time to disassemble part i [s];
- $t_{test,i}$ = time to repair and test part i [s];
- $t_{reass,i}$ = time to reassemble part i [s].

TCs that wish to develop a method to determine a product reparability index (R_{repair}) or establish time for repair of a priority part ($t_{repair,i}$), should consider the testing and repair actions and decide on a method to assign time values to them (e.g. providing a table of values for $t_{test,i}$). TCs should also decide how to include disassembly and reassembly time and a method to determine it, as well as reference times ($t_{ref,i}$). To establish disassembly and reassembly time testing methods are proposed in B.3.1.2.

B.3.3 Product reusability index

Harvesting of reusable components could be done for potential reuse of components as spare parts or for remanufacture. Similar to the product reparability index, a product reusability index can be developed:

$$R_{reuse} = \sum_{i=1}^{p} \frac{t_{reuse,i}}{m_i * W_{need,i}} * \frac{m_{tot}}{t_{ref}} \quad R_{reuse} \geq 0; \text{ [dimensionless]}$$

where:

- R_{reuse} = Product reuseability index [dimensionless];
- p = number of parts considered [dimensionless];
- m_i = mass of part i [kg];
- $W_{need,i}$ = overall weighting factor of part i, [dimensionless];
- $t_{reuse,i}$ = Time for reuse of part i [s];
- t_{ref} = reference time [s];
- m_{tot} = total mass of the product [kg].

Time for reuse of a priority part ($t_{reuse,i}$) is the sum of the time needed to do disassembly and reassembly, as well as time needed to do any refurbishing and testing of the proper functioning of the part:

$$t_{reuse,i} = t_{dis,i} + t_{test,i} + t_{reass,i} \quad [s]$$

where:

- $t_{dis,i}$ = time to disassemble part i [s];
- $t_{test,i}$ = time to refurbish and test part i [s];
- $t_{reass,i}$ = time to reassemble part i [s].

TCs that wish to develop a method to determine a product reusability index (R_{reuse}) or establish time for reusability of a priority part (t_{reuse}), should establish what prerequisites to proceed with the calculation of a product reusability index are, and how a manufacturer shall document these. They shall use the classification of required tools, skills and service environment and service conditions (available product interface and firmware updates; availability of spare parts and of information needed to carry out the repair) developed according to section B.1.

TCs should also consider the testing and refurbishing actions and decide on a method to assign time values to them (e.g. providing a table of values for t_{test}). TCs should also decide how to include disassembly and

reassembly time and a method to determine it, as well as reference times ($t_{ref,i}$). To establish disassembly and reassembly time testing methods are proposed in B.3.1.2.

B.3.4 Product upgradability index

Similar to the product reparability index, a product upgradeability index can be developed:

$$R_{upgrade} = \sum_{i=1}^{p} \frac{t_{upgrade,i}}{m_i * W_{need,i}} * \frac{m_{tot}}{t_{ref}}$$ $R_{upgrade} \geq 0$; [dimensionless]

where:

- $R_{upgrade}$ = Product upgradability index [dimensionless];
- p = number of parts considered [dimensionless];
- m_i = mass of part i [kg];
- $W_{need,i}$ = overall weighting factor of part i, [dimensionless];
- $T_{upgrade,i}$ = Time for upgrade of part i [s];
- t_{ref} = reference time [s];
- m_{tot} = total mass of the product [kg].

Time for upgrade of a priority part ($t_{upgrade,i}$) is the sum of the time needed to do disassembly and reassembly, as well as time needed to do any resetting and testing of the proper functioning of the part:

$$t_{upgrade,i} = t_{dis,i} + t_{test,i} + t_{reass,i}$$ [s]

where:

- $t_{dis,i}$ = time to disassemble part i [s];
- $t_{test,i}$ = time to upgrade and reset part i [s];
- $t_{reass,i}$ = time to reassemble part i [s].

TCs that wish to develop a method to determine a product upgradeability index ($R_{upgrade}$) or establish time for upgradeability of a priority part ($t_{upgrade}$), should establish what prerequisites to proceed with the calculation of a product upgradeability index are, and how a manufacturer shall document these. They shall use the classification of required tools, skills and service environment and service conditions (available product interface and firmware updates; availability of spare parts and of information needed to carry out the repair) developed according to B.1.

TCs should also consider the testing and resetting actions and decide on a method to assign time values to them (e.g. providing a table of values for t_{test}). TCs should also decide how to include disassembly and reassembly time and a method to determine it, as well as reference times ($t_{ref,i}$). To establish disassembly and reassembly time testing methods are proposed in B.3.1.2.

1044
1045 (informative)
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1047 **XXX**

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