PROMPT

Premature Obsolescence Multi-Stakeholder Product Testing Program

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Content

1 Introduction

The final deliverable 6.3 of PROMPT work package 6 summarizes the main findings of the work done in work package 6. It includes a of the General test programme (GTP) based on the learning of the four case studies done on smartphones, cordless vacuum cleaner, TVs and washing machines. Additionally, conclusions, barriers, and future research suggestions from the three testing categories: reliability, repairability and user & market aspects are discussed. The results of the four case studies can be found in deliverable 6.2. The work of work package 6 is based on the previous research of the PROMPT work packages 3 to 5 and the corresponding deliverables, these set the basis of the work in work package 6.
The aim of the PROMPT Consortium is to create a feasible and reliable test program that provides relevant results about the reliability and repairability of the smartphones and the user and market aspects that influence the consumers in the decision to keep or repair a product.

The process to prepare this final version of the test program includes the following steps:

Dates	**Task**	**Information**
Jan 20 – Apr 21	Research of the work packages	Review of previous PROMPT Research - WP3 Reliability assessment - WP4 Evaluation of design for repair or reuse - WP5 User and market aspects that influence premature obsolescence Additional literature review (standards, research articles and presentations) regarding possible tests and evaluations
Apr 21	Draft TP	Draft product specific and general test programmes created with the help of the consortium
Jul 21	Workshop with consumer organizations	Presentation of the product specific test programme to ICRT consumer organizations, and adaptation of their feedback
Sep 21	Selection of samples	Selection of 5 different models for each product specific case study to be tested in 2 different laboratories taking into account the market share, their technology and their price
Sep 21-Jan 22	Lab selection and contracting	Lab tender process and lab selection based on costs, lab experience
Dec 21- Dec 22	Tests in laboratories	Test execution starting with long term reliability tests
Aug 22	Analysis of first results	First results complete, analysis of repeatability, reliability and feasibility of the test methods
Oct 22	Workshop with industry	Presentation of the product specific test programme and first results to industry stakeholder, and collecting of their feedback
Nov 22	Visits to laboratories and virtual meetings	Review of the results of the tests, discussing repeatability and relevance
Dec 22	Retests and final results	Finalisation of the laboratory tests
Dec 22-Mar 23	Evaluation of test results	Discussion and evaluation of test results (weighting, adaptation of test methodologies)

Feb 23	Meeting with labs experts	Gathering the lab expert feedback about the clearness of the instructions given in the draft test programmes, the difficulties they found performing the tests and suggestions on how to obtain the same results (or better results) in a more economic procedure in terms of time and money
Mar 23	SPO evaluation meeting	Implementation of an evaluation and determination of final test programme

With all this feedback, we present here a final proposal of a general test programme, that could be used by consumer organizations or any other organization willing to test the reliability, repairability and the user and market aspects of a product.

2 Validated General Test Programme

2.1 Introduction to the General Test Programme

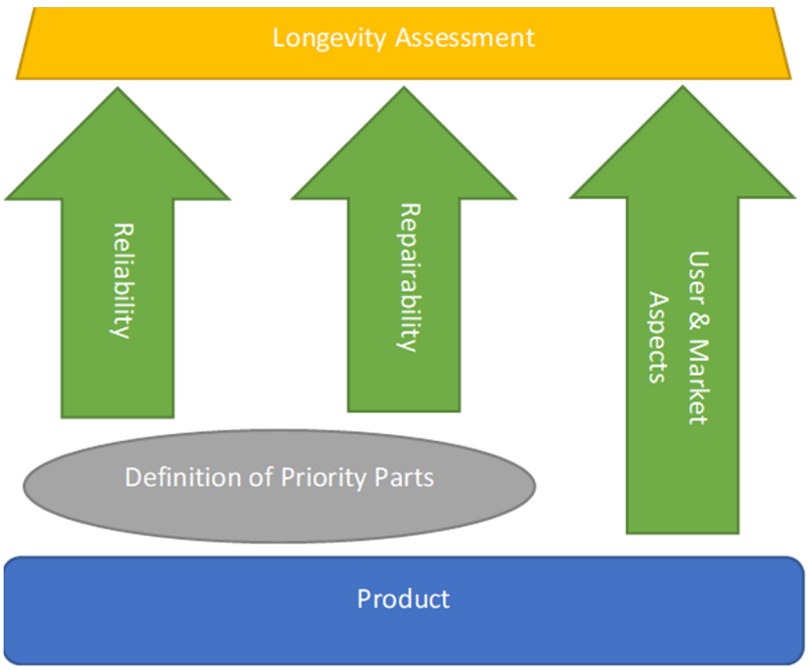
2.1.1 Objective

The main goal of the general test programme (GTP) is to set up a general approach to test for premature obsolescence for selected electrical and electronic equipment (EEE). It has the objective to support the assessment of the longevity of consumer products when they are put on the market. The general test programme will serve as a starting point to define product specific testing programmes. Within the PROMPT project four product groups were analysed in detail: mobile phones, (smart) televisions, washing machines and vacuum cleaners. The general test programme was modified according to the findings of the four case studies. It represents a manual to design a test programme for premature obsolescence for electrical and electronic equipment and defines steps and general criteria.

2.1.2 General approach

Sustainability is the ideal goal of our today's society. This includes responsible use of resources for our and our planet's future. One part of the solution is the longer use of products and the prevention of premature obsolescence. Extension of product lifetime can be promoted by enabling consumers to recognize long lasting products before buying it. The problem is that products lifetime can only be exactly determined when the product has reached the final limiting state. To ensure a long usage time of products, three factors are important: reliability, repairability and user & market aspects. All three are addressed in the following test programme. To reach a good feasibility and still meaningful results the testing for reliability and repairability are based on defined priority parts. The user and market aspects cover additional characteristics of the product and the corresponding design, support, service and selling framework provided by the manufacturer. It is important to note that some proposed tests are originated from user & market perspectives but for practical reasons listed under repairability or reliability sections (for example: maintenance).

Figure 1: Scheme of the test approach



The tests consist of practical lab tests performed by lab experts and a questionnaire part collecting necessary information provided by the manufacturer. The questionnaire is filled by the lab experts by using information of the manufacturer (manuals, online manuals, websites, …). After filling the questionnaire, the results are sent to the manufacturer to cross check and ensure the quality of the questionnaire results. The questionnaire can be found in the 4.1.

2.1.3 Priority parts

A testing programme for premature obsolescence underlies several constraints. First, it has to be feasible for different stakeholders such as consumer organisations or market surveillance authorities. Furthermore, it needs to respect budget and time constraints. The results of a premature obsolescence test need to be published closely to the market entrance of the tested product, to inform consumers and support them to make a sustainable decision for a certain product.
For this reason, focusing on priority parts is a reasonable strategy to reduce testing time and costs and still achieve valuable information on product lifetime. The procedure to define product specific priority parts is based on the standard EN 45554:2020. According to the standard, three criteria define a priority part:

- The likelihood of the need to replace or upgrade the part
- The suitability of the part for reuse
- The functionality of the part

While the suitability of the part for reuse is an essential aspect of the inner loops of the circular economy, it plays a less crucial role for premature obsolescence, which is why this criterion was excluded from the procedure. The procedure assigns a relevance value for each component of the product based on the two remaining criteria, functional relevance, and failure likelihood. The assignation rule is presented in the following table:

Table 1: Assignation rules for the relevance value

Relevance value		Failure likelihood		
		Low	Medium	High
Functional relevance	Low	0	0	0
	Medium	0	1	2
	High	0	3	4

Components with a high likelihood of failure and a high functional relevance score a 4. The relevance value of components with a low failure likelihood and/or a low functional relevance is 0. If both criteria are rated medium, the resulting relevance value is 1. The failure of a relevant component is more important for consumers and leads to increased likelihood of the replacement of the product. Thus, the relevance value for components with high functional relevance and medium failure likelihood is set to 3. On the other hand, it is set to 2 for components with medium functional relevance and high failure likelihood. This evaluation provides a list of the components of the product with corresponding relevance values. The priority parts are defined based on this list. All components with a relevance value of 4 are priority parts. Depending on available resources (e.g. consumer feedback, repair statistics, etc.) also parts with a relevance value of 3 might be included. The resulting list of priority parts should be cross checked with already existing sources (e.g. Eco-design regulations, French repair index, …).
The functional analysis assessment is based on the FAST method in EN 12973 common functional definitions of certain products. The categories of the functional relevance are:

High	Part provides primary function (function fulfilling the intended use)
Medium	Part provides secondary function (function that enables, supplements, or enhances the primary function(s))
Low	Part provides tertiary function (function other than a primary or a secondary function)

The failure likelihood assessment is based on available data for reliability. Valid data are based on physical testing, statistical surveys, calculations and field data. Accidental breakdowns and normal wear-out shall also be considered as sources of part failure. Possible sources for such data are reports of the European Joint Research Center, consumer surveys from consumer organizations, repair organizations, scientific articles or

reports of industry bodies or manufacturers. These data could be either quantitative data or qualitative data, whereby quantitative data on failure rates should be preferred. Based on the size, depth and source the quality of the data is assessed. The likelihood of failure is depending on the product model. But the test of a product is usually conducted close to its market launch. Thus, there is no model specific reliability data available. For this reason, reliability data of the product category are used for the definition of the priority parts. These data should be as up to date as possible. That means also that the priority part list could change in the course of time. For qualitative data, the components are clustered in three groups of failure likelihood: High, Medium, Low. For quantitative data, the assessment is based on the ordered list of failure likelihood, where the first entry is the most likely failure and the last one the most unlikely failure. With respect to the data quality and the estimated lifetime of the product category the limits for the categories High, Medium, and Low are set. Empty categories are valid (e.g., no component matches the criterion for "Low"). A more detailed procedure is not available due to the different characteristics of the data (e.g., repair statistics, surveys or results of reliability tests).

Additional remarks, if there are indications that failure likelihood or functional relevance of parts differ within a product group according to technology, priority parts may need to be defined for each technology. Also, a crosscheck of the priority parts with other methodologies (e.g., French repair index) is reasonable.

2.2 Reliability

Reliability is an important characteristic of a product. According to the standard EN 45552:2020, reliability is the probability that a product functions as required under given conditions, including maintenance, for a given duration without limiting event. The reliability tests focus on the defined priority parts. Due to the wide variety of products and therefore also priority parts, no specific test program for every priority part can be defined. Instead, some general remarks and guidelines are proposed. Also the testing of maintenance is described.

2.2.1 Reliability tests

The reliability tests can be performed on the single disassembled priority parts or on the whole product. It can be reasonable to combine certain tests for different priority parts. For example, during the aging test for a vacuum cleaner battery its engine can be tested simultaneously. In general, two types of failures are important, intrinsic and degradation failures. Intrinsic failures are caused by overload (e.g., display cracks due to accidental drop), degradation failures are caused by aging or wear of materials or components due to use or progress in time or exposures to certain conditions (capacity decrease of batteries). It should be noted that both failure types are also interacting. For example, a degraded polymer housing is more likely to break under stress. Therefore, due to their different nature, different types of reliability tests are needed. To specify reasonable loads, an usage scenario and an expected lifetime needs to be defined.
To assess intrinsic failure, a stress test is a reasonable approach. Therefore, the failure mechanism needs to be analysed, and a corresponding test has to be defined. The conditions of the stress test should be chosen with respect to scenarios of expectable misuse/overload. That means the chosen stress limits can exceed the limits published by the manufacturers but must still be based on realistic assumptions. For illustration, most smartphone manufacturers do not define a drop of a phone as a normal use, but in daily life this happens on a regular basis.
The defined stress levels can then be used as pass/fail criteria. If the failure mechanism is sensitive to various conditions (e.g., impact angle and impact spot in drop tests) multiple runs are recommended.
To assess degradation failures, accelerated aging and wear tests are performed. Based on the degradation mechanism, different types of tests are conducted. If the failure is caused by aging effects an accelerated aging test is reasonable. Due to an increased test temperature, physico-chemical processes are accelerated. A first approach for acceleration is the Van't Hoff rule. The rule states that the speed of chemical reactions is doubled, at least, for each 10°C rise in temperature. The rule is an approximation that works best when temperatures approximate those under which the reaction normally occurs. Additionally, the use of high temperatures test could also lead to new failure mechanisms, which are not occurring during the intended use. Therefore, the acceleration is limited. During planning of the test, it needs to be checked if the achievable acceleration is matching the expected lifetime of the product. If the accelerated ageing test can only represent the early life of the product, it is not reasonable to conduct the test.

For failure based on wear out due to usage, an accelerated cyclization test is appropriate. Therefore, the normal use of the product is imitated. But only the most challenging usage scenarios (highest wear effect) are considered in the test and any breaks are excluded. Also, an adjusted overload could be included.

2.2.2 Maintenance

The maintenance test includes questionnaire part (collection of information provided by the manufacturer) and a practical lab test by the lab experts.

2.2.2.1 Maintenance instructions & indicators

The manual is checked for the presence of maintenance activities. The described maintenance activities are listed. The manufacturers answers regarding maintenance support are filled. For any step by step or video guides for maintenance, their source is recorded (manufacturers website). The quality of the maintenance guides (manual) is assessed by 2 lab experts from the consumer's point of view (rating from 0.5 - poorest to 5.5 - best). Criteria are understandability, readability and structure. Meaningful comments support the assessment (what is missing?, What is well described?, self-explaining pictures, …).
The presence of indicators for physical maintenance is checked. Therefore, the manual is checked for information for maintenance intervals and product and manual are checked for indicators (Warning light or sound …), that request the consumer to maintain the product. The results are listed. The product is allocated to one of three categories. The three categories are: category 1 – no information and indicators for maintenance, category 2 – only information available but no indicators on the product and category 3 - maintenance information and indicators are available. A meaningful comment supports the allocation.
The presence of indicators for preventing misuse is checked. Therefore, the manual is checked for information for correct use (loads, temperatures, …) and product and manual are checked for indicators to avoid misuse (Warning light or sound, safety shut down procedure, …). The results are listed. The product is allocated to one of three categories. The three categories are: category 1 – no misuse information and indicators, category 2 – only information available but no indicators on the product and category 3 - misuse information and indicators are available. A meaningful comment supports the allocation.
The presence of indicators for software updates checked (only applicable when updates are supported by the manufacturer). The information in the manual regarding updates are checked. The product is allocated to one of three categories. The three categories are: category 1 – no indication of new available updates, category 2 – only an indication but the update process has to be conducted by the consumer manually and category 3 - product updates (after user approval) software automatically. A meaningful comment supports the allocation.

2.2.2.2 Maintenance activities

The in the manual described maintenance activities are performed and assessed regarding their time, effort, handling by two lab experts from the consumers point of view. The instructions in the manual are followed. If any additional tools (not supplied with the product) are needed, it is recorded. The rating for each maintenance activity from 0.5 - poorest to 5.5 - best. Meaningful comments support the assessment (what is hard to do?, What takes time?, …). If any standard maintenance activities are not described in the manual, they are tested as well.
The presence of self-cleaning, automatic updates, self-optimization and similar is checked and listed.

2.2.2.3 Cleaning

The cleaning process of the exterior of the product is evaluated by two experts from the consumer's point of view. Criteria are the surface texture and hard-to-reach places (corners/edges). The product is allocated to "hard to clean" or "easy to clean". A meaningful comment supports the allocation.
The manual is checked for the presence of cleaning advice.

2.2.2.4 Supplies & consumables

The manufacturers answer regarding protective measures, cleaning supplies and consumables of the questionnaire are verified. If any protective measures, cleaning supplies and consumables are stated by the

manufacturer, their availability is checked and recorded (manufacturers website, big online shops (maximum three)).

2.2.2.5 Updates

A software update is a process of maintenance and ensures the functionality of a product. This could include for example: fixing of programming errors, updated databases, closing of security gaps. Processes adding new functionalities or aesthetics or leading to a major increase of performance or capacity of a product are considered an upgrade (see below).
The answers of the manufacturer regarding updates of the questionnaire are verified. If any guaranteed period of availability of updates are stated by the manufacturer, the existence of an official statement of the manufacturer is checked and recorded (on the product, manufacturers website, manual). Comments on any peculiarities (unclear conditions, hard to find, …) are desired. If no answers of the manufacturers are available, experts try to find the needed information within 15 minutes using the manual, manufacturers website and common search engines.

2.3 Repairability

2.3.1 Repair information & policy

The questionnaire is filled. For all answers the source has to be recorded (manufacturer's website, manual, product). Comments on any peculiarities (uncomplete, hard to find, …) are desired. If no answers of the manufacturers are available, experts try to find the needed information within 15 minutes using the manual, manufacturer's website and common search engines. Only information provided by the manufacturer are taken into account.

2.3.2 Disassembly assessment

In this section, the physical properties for disassembly are assessed. The methodology is based on EN 45554:2020 and its definitions and uses the eDim methodology. The specimens are dissembled to reach the priority parts. All disassembly actions to disassemble a certain priority part are recorded. This applies for all priority parts. An Excel Sheet to record all necessary data during the disassembly is provided by the client. The Excel file also provides additional information on how to conduct the disassembly and how to collect the needed data (Tab "Instructions"). More information can be found in the Appendix.
The disassembly consists of multiple disassembly actions. A disassembly action includes tool change, identifying fasteners, manipulation, positioning, unfastening, and removing component. All disassembly actions are recorded in the provided excel file (Tab "2_eDim"). The excel file also includes a full list of disassembly actions (Tab "Instructions").
Fasteners are classified in three categories: reusable (A), removable (B) or neither removable nor reusable (C). The used tools are classified in five classes A, B, C, D and E according to EN 45554:2020. Class A represents tools, which are supplied with the product or spare part or basic tools (see Table A.3 in EN 45554:2020). Product group specific tools are used in class B. Class C includes any proprietary tools, which are not belonging to class A or B. If the needed tool is not commercially available, it is considered class D. Class E is for hypothetical not existing tools (no existing tool can fulfil the task). Not all classes may apply to every type of product. Many processes, such as for instance the removal of fasteners and connectors, can be completed with several different types of tools. In order to assess the applicable tool category, the most appropriate tool of classes A or B is chosen.
The repair scenario is defined by an expert in a workshop environment. This represents the repair scenario for an independent repair shop. Thus, tools of class C to E are only used if no class A or B tool can do the job. Additionally, each disassembly action is checked regarding its safety hazards. The risk of injury either during or after repair is assessed based on two factors: the likelihood of an incident occurring, and the severity of the consequences if an incident occurred. This includes electrical, thermal, or mechanical risks during or after the repair.
If official repair manuals of the manufacturer are available, they define the disassembly routes and procedure. If no official manuals are available, open-source information is used to find the best disassembly.

The first disassembly serves to get familiar with the model, to find the best disassembly route and to record the disassembly actions. A second disassembly on another specimen of the same model is performed to obtain the needed time measurements for each disassembly action.
During the disassembly process. the following data is gathered by filing the provided excel file creating a disassembly protocol for the priority components:

- Component
- Fastener type
- Tool used and tool type
- Action
- Repetitions (if multiple motion action)
- Force/Intensity
- Whether positioning of tool or component is required
- Whether product or component manipulation was required
- Fastener Identifiability
- Repair Safety
- Real time for action (second disassembly)

2.3.2.1 Tools

All used tools are listed with description and a meaningful picture. The classification of the different tools is given in the appendix.

2.3.2.2 Visual Repair map (optional)

In order to simplify and visualize the product disassembly architecture, it is meaningful to also have a visual repair map. This repair map shows a decision tree like approach to access the components. So, we would like to have a graphical representation of the disassembly actions called the disassembly map. Although being very helpful this is still a secondary priority. The visual repair map should also include the safety hazards related to each action needed to disassemble the priority part and the tools needed.

2.3.2.3 Filming of the disassembly (optional)

In order to simplify and visualize the product disassembly a filming of the procedure is useful. During the second disassembly (time measurement) the procedure is filmed with two cameras. The first one films the repairer point of view with direct view on the hands, tools, and components of the product (a bodycam is recommended). The second camera provides the top view perspective and is mounted in a reasonable distance straight above the product respectively the repair place.

2.3.3 Diagnosis

The questions regarding diagnosis of the questionnaire are verified. For every information/manuals the soure is recorded (manufacturer's website, manual, product). Comments on any peculiarities (uncomplete, hard to find, …) are desired. The experts try to find the needed information within 15 minutes using the manual, manufacturer's website and common search engines.
Additionally, the quality of the trouble shooting section is assessed by 2 lab experts from the consumer's point of view (rating from 0.5 - poorest to 5.5 - best). Criteria are understandability, readability, completeness (common errors, service contact) and structure. Meaningful comments support the assessment (What is missing?, What is well described?, self-explaining pictures, …).

2.4 User & Market aspects

2.4.1 Product appearance

The reliability of the product appearance is tested regarding scratch resistance and surface aging. A scratch test according to DIN EN ISO 1518 with a hardness test pencil (ERICHSEN, Model 318S) or similar is conducted. This

pencil is equipped with a spiral spring and a carbide ball tip of 1 mm diameter (in accordance to ISO 1518). The test load of the spring can be adjusted ranging from 0 to 20 N.is performed. The resistance to penetration by a test tip is evaluated. The procedure determines the maximum load to not create permanent visible scratches. The scratch resistance is testes for all product surfaces, which are endangered during normal use of the product. In case of doubt, the parts are determined in consultation with the SPO. If the same material is used in different parts of the product, it only needs to be tested once. The tested part and the determined minimum load are recorded.
The surface aging test aims on the discolouration caused by aging of polymer surfaces. Thus, it is only performed for visible polymer surfaces. The test is performed according to ISO 4892-3. Therefore, smaller specimens of the surface are cut out and exposed to UV-radiation. Duration, intensity, and other test conditions should reflect the exposure during the product lifetime and are determined in consultation with the SPO. After the UV-Exposure the lab experts allocate all samples in comparison to the neat surfaces to the categories "no colour change", "light colour change", "significant colour change". Further peculiarities are listed in comments.

2.4.2 Product design assessment

2.4.2.1 Timeless Design

Two experts evaluate the timeless design of the product from the consumer's point of view. The timeless design assessment includes the colour and the shape of the product.
The colour of the product is protocolled (maximum three main colours) and allocated to one of two categories. The colour evaluation focusses on the during operation visible colour of the product. The colour of usually not visible sides of a product (i.e. bottom or backside) are irrelevant.

- Colour category 1
  - One main colour (white, black, grey,)
  - No striking highlights of bright or trendy colours
- Colour category 2
  - One or two main colours (white, black, grey, green, blue or red)
  - Saturated or dark colours
- Colour category 3
  - Colour mix of three or more colours
  - Trendy, bright or striking main colours

The shape of the product is allocated to one of three categories.

- Shape category 1
  - Complex design (i.e. different forms and shapes combined)
  - Not a prototypical design (design is significantly deviating from the norm)
- Shape category 2
  - (Moderately) complex design (i.e. relatively simple shapes)
  - Prototypical design (i.e. not too deviating from the norm).
- Shape category 3
  - Simple shapes (i.e., uniform shapes)
  - Prototypical design (i.e., not too deviating from the norm).

The allocation is supported by meaningful comments (striking design characteristics) and photos.

2.4.2.2 Perceived Robustness

Two experts evaluate the solidness perception of the product from the consumer's point of view and give a score from 0.5 (low perceived robustness) to 5.5 (high perceived robustness). The evaluation includes sounds (e.g. rattling during operation), undesired movement or clearance, perception of control elements (e.g. backlash of buttons, switches) and movable parts. The result is supported by a meaningful comment. Additionally, the weight of the product is measured and recorded.

2.4.3 Upgrades

An upgrade is a process of increasing the functionality, performance, capacity or aesthetics of a product and may involve changes to its software, firmware and/or hardware.
The upgrade section of the questionnaire is filled. If any upgrade preparations or upgrades are stated by the manufacturer the source is recorded (on the product, manufacturers website, manual). Comments on any peculiarities (unclear conditions, hard to find, …) are desired. The experts try to find the needed information within 15 minutes using the manual, manufacturers website and common search engines. Only publicly available information by the manufacturer is considered.

2.4.4 Brand policy

2.4.4.1 Brand communication regarding product lifetime

The product manual and the product packaging are checked for any concrete statements regarding the product lifetime (years, cycles, etc.). Existence (yes, no), location (manual, packaging) and the stated lifetime of such statements is recorded. Comments on any peculiarities are desired.

2.4.4.2 Circular business models

The circular business model section of the questionnaire is filled. If any circular initiatives are stated by the manufacturer the source is recorded (manufacturers website, manual). Comments on any peculiarities (unclear conditions, hard to find, …) are desired. If no answers of the manufacturers are available, experts try to find the needed information within 15 minutes using the manual, manufacturers website and common search engines. Only publicly available information by the manufacturer is considered.

2.4.4.3 Free extended warrantees

The free extended warrantees section of the questionnaire is filled. If a free extended warrantee is available according to the manufacturer, the source and conditions of the warrantee is recorded (manufacturers website, manual). Comments on any peculiarities (unclear conditions, hard to find, …) are desired. If no answers of the manufacturers are available, experts try to find the needed information within 15 minutes using the manual, manufacturers website and common search engines. Only publicly available information by the manufacturer is considered.

Summary / key findings

2.5 Reliability

The reliability section consists of the reliability tests and the test for maintenance support and activities.

2.5.1 Reliability tests

In the reliability tests cyclic aging (example: battery tests, washing machines) and accelerated aging in climate chamber (electronics) were used. Both test types turned out very costly and time consuming. For some specific cases, depending on product design characteristics, certain reliability tests can be replaced by checking information (for example cordless vacuum cleaner – carbon brushes yes/no). A Reduction of test cycles combined with more stressing scenarios is possible. But the direct correlation to the real-life usage time is lost. In previous investigations on washing machines a typical mix of washing cycles and an average number of use cycles per week were used. By using more stress full washing cycles (spin and rinse + hot wash), we were able to reduce the testing time and similar results occurred. From a pragmatic point of view the reduction of cycles is meaningful. But the problem is the fast-moving market, which makes the testing time critical. Cyclisation tests often take approximately one year (in PROMPT: battery tests and washing machine test). That means the published results after one year of testing are not relevant for consumers anymore.
Accelerated aging in a climate chamber is very costly and time consuming. This approach for electronic components works but the definition of proper testing condition, as well as the high effort prevents a regular use of these kind of tests for consumer organisations.
Stress tests are usually fast and efficiently conducted. The key feature is the existence of standardized tests for a product category. That means the used equipment, stress conditions and test procedure is already designed and approved. Costs and time effort is reduced. Such tests are also accessible for consumer organisations and market surveillance. But not for all product categories standardized methods are defined or mandatory. For example, a standardized methodology to test the reliability of TVs is not established.

The used methodologies in the PROMPT validation tests were performed successfully. A complete transfer to the regular work of the consumer organisations is unlikely because of the high effort in time and budget.

2.5.2 Maintenance

The maintenance tests are easy to perform but still time consuming. Some of the needed information of the questionnaire part are hard to find. Some lab experts doubt the ratio between the effect of the results and the effort put in the tests. It is important to test the maintenance support because easy maintenance leads to longer product lifetime.

2.6 Repairability

In the repairability assessment three subtopics were addressed: repairability information & policy, disassembly assessment and diagnosis. The key findings of all subsections are summarized in the following sections.

2.6.1 Repair information and policy

The repair information and policy of the manufacturer is the key topic in repairability. No matter if you want to use a repair service or do a repair on your own, you are relaying on spare part supply and repair information/manuals. Assessing these properties with the questionnaire worked. Unfortunately, the cross check with manufacturers did not work all the time. Also, different information in different languages/countries lead to a complex assessment. A required support with repair information and services for all products within the EU would simplify the assessment. Furthermore, some information is placed in restricted websites. Because of the consumer organizations policy not to reveal the testing laboratories, registration or qualification proof is not possible. Thus, information on restricted websites cannot be assessed.

2.6.2 Disassembly assessment

The used eDIM method works well and provides reliable results to compare different products. According to the lab experts it also reflects the real disassembly effort quite well. Also, it was not a problem to find and contract laboratories with the needed expertise to perform these tests. In comparison to other methodologies the biggest effort is the calculation of proxy times according to protocolled disassembly actions. Compared to a step counting method, eDIM is more accurate because it considers the different complexity/effort of different steps. For example, opening of a glued smartphone may be counted as one step. In comparison a smartphone with snap fits and screws may be counted 2 steps. In reality, a phone with snap fits and screws is opened faster. Just counting steps may lead to wrong assumptions about the complexity of the disassembly. To simplify the disassembly assessment PROMPT developed an excel sheet for standardized logging of the disassembly and automatic calculation of the proxy times. One of the biggest arguments against consumer repair is the safety of the consumers. So, a safety assessment based on the likelihood of an accident and its potential consequences was included. Thermal, mechanical, electrical and post repair risks were considered and included in the disassembly protocol. Manufacturer can design products, which are safe to repair. Due to the more complex approach also some drawbacks occurred during the tests. The definition of some disassembly action needed some improved specification (unique definitions). By using other product categories also new action might need to be introduced. Another challenge are glued surfaces. There is not ready to use procedure for glued surfaces. The disassembly of glued surface can be quite different, depending on the glue type, its age and temperature and others. More research needs to be done in this direction.
For smartphones the reassembly was also conducted to investigate the differences between disassembly and reassembly. The feedback from the experts stated that usually just performing the disassembly is reasonable. This procedure may save some time and budget. But for a new product category this approach has to be discussed again and might end with a different conclusion.
The PROMPT approach focusses on the replacement of a faulty part. In future research the repair of faulty parts might be of interest.

2.6.3 Diagnosis

Diagnosis might be the smallest test part in the repairability assessment, but it is of high importance for the repair procedure. Consumers tend to not repair their product if they do not know what is wrong. The diagnosis is a highly complex topic. Various failure might occur during the products lifetime and demand different failure detection and indication. With respect to the PROMPT resources a detailed test of different failure modes and their detection and indication was not possible. Basic features and support of the manufacturer regarding diagnosis (for example existence of failure code databases) and checking of the troubleshooting section in the manual for completeness and comprehensibility were performed. Those basic tests allow an insight in the manufactures design process and whether failure diagnosis was considered or not. To fully check all aspects of diagnosis a new research project is recommended.
But even doing the basic approach here leads so some limitations. Similar to other repair information, diagnosis information is sometimes placed at websites with limited access. That ranges von simple registration of a product to qualification as a repair service approved by the manufacturer after certain procedure/training to get the needed access.

2.7 User & market aspects

The most aspect of the PROMPT test programme is the inclusion of user & market aspects. Some of the topics are also included in the other parts of the test programme (for example: repair information, maintenance, …).

2.7.1 Product appearance

The test for the aging or destruction of the appearance of a product was a success. The tests for surface scratches and colour change under aging (UV-exposure) were easy to perform and within time and budget constraints. It turned out that both tests are only meaningful for polymer surfaces. The UV-exposure produced significant results on white polymer surfaces. Other surface did not show a significant change. Thus, the application of these tests can be limited to those kinds of surfaces.

2.7.2 Timeless design

A timeless design has been proposed in the literature as a means to lengthen consumers' appreciation of the aesthetic value of a product (Flood Heaton & McDonagh, 2017; Mugge et al., 2005; Wallner et al., 2020). As a result of fashion changes, products can lose (some of) their aesthetic value over time. However, not all design styles are equally susceptible to such fashion changes. Some design styles enjoy short-lived popularity and disappear quickly, while others are appreciated over an extended period of time. Timeless or classic designs are visually simplistic, ordered, and harmonious. Furthermore, timeless designs generally make use of neutral (i.e., white, black, grey) colours. People's evolutionary desire for symmetric and simple appearances (Snelders, Mugge, & Huinink, 2014; Veryzer Jr & Hutchinson, 1998) is suggested to be the underlying psychological mechanism for the long-term preference of timeless designs.

During the testing of the different products, the experts struggled with scoring the products on the criterion timeless design. This may have several reasons. First of all, at the moment when the testing took place (2022) most products belonging to the categories of smartphones, TVs, and washing machines did not differ strongly in their design. Specifically, TVs and smartphones had simplistic, rectangular shapes and a black colour, while washing machines had a rectangular share with a round-shaped door and a white colour. In general, these shapes tend to follow the guidelines related to a timeless design well. In today's consumer tests, experts are used to search for differences between the test products in order to ensure that the tested products score differently on the criteria. However, for the criterion of timeless design and the current set of smartphones, TVs, and washing machines, this may have resulted in highlighting very minor differences (e.g., different base of a TV) in the designs. Scoring products based on such minor differences may be interpreted differently by experts easily, resulting in inconsistent scores. In fact, timeless design suggests a holistic appreciation of the entire design as a whole, and thus minor differences are unlikely to influence the degree to which it adheres to this design style, and consequently, will influence consumers' appreciation of the product's aesthetic value over time. We believe that for smartphones, TVs, and washing machines probably the current market does not provide a measurable variety and all product variants would receive the same value. However, this does not mean that this will be the case for future products within these categories.

Second, the developed sub-criteria for the timeless design criterion may have negatively affected the validity of the test instrument. The experts had adjusted the timeless design criterion to adhere to their current way of testing by relating it to specific parts of the product. For example, for the vacuum cleaner, the body, nozzle, and hose were scored separately. However, a timeless design suggests a holistic evaluation and thus the overall evaluation will not necessarily be the same as the sum of the parts. We would advise changing the criterion to one overall score of the design.

Third, the testing phase demonstrated that experts experienced difficulties in scoring timeless design because they were unfamiliar with the concept of a timeless design. As experts involved in the testing phase are not design experts, they need more detailed knowledge of what timeless design entails to be able to assess this in a reliable and valid manner. Accordingly, we would like to recommend preparing visual examples of different products scoring high, medium, and low on timeless design in order to help the experts score this criterion successfully. These visual examples should be provided in addition to the textual explanations and should be created by design experts who have a good understanding of what the design style entails. Preferably, these visuals should include a large range of products so that the input can be used for testing various product categories.

Finally, experts raised some concerns about the desirability of this testing criterion as they expected it to lead to rather boring, similar-looking, and non-colourful products. Although we feel that a timeless design would leave ample room for design variety and these designs are generally aesthetically appreciated, we acknowledge that adhering to this design style may reduce the novelty and use of colour in product designs. It is however questionable why this would be problematic for the purpose of the PROMPT testing program. For example, it may be that product designs that follow a short-lived design style can bring about positive emotions among consumers when these are introduced. However, the testing program is not intended to test for positive emotions at purchase. In contrast, it aims to test for longevity and this specific criterion is intended to test for long-term aesthetic appreciation of the product design. As it is likely that such colourful designs will go out of fashion relatively soon, it is only reasonable to give these products a low score on this test criterion.

2.7.3 Perceived robustness

A product appearance with high perceived robustness can indirectly prevent premature obsolescence because such a strong, sturdy, and reliable appearance will bring about relatively high expectations regarding the lifetime of a product. High expectations about the lifetime are transferred into an extended product's mental book value (Van den Berge et al., 2021). This means that if consumers expect the product to last relatively long, the product value remains high over time, and it will take more time before consumers will feel that the product has served its time and it is time for its replacement. Furthermore, consumers may be more inclined to consider repairing such robust products when a defect occurs. Based on the former, we included perceived robustness as a criterion in the testing program. To measure the perceived robustness, it is important to realize that this concerns perceptions and is thus different from the actual reliability of a product, which is covered in the criteria of WP3.

An appearance is considered to be robust when the product has a low sensitivity to variation for example intolerances or noises that can during the manufacturing and assembly of different components (Park et al., 2006). We expect that especially components that are touched by consumers during use, such as buttons or valves, will contribute to this element of perceived robustness. Also, a product that is relatively heavy in terms of its weight is associated with a more robust design (Mugge et al., 2018). However, it is important to consider the potential negative effect of robust designs on consumers' preferences. Robust and massive shapes may not be aesthetically appreciated by all consumers. A study on product appearances showed that 'tough' designs (e.g., massive and solid appearance) only resulted in higher aesthetic appreciation by one out of the four distinguished consumer segments, which may thus prevent the adoption of physically durable designs (Snelders et al., 2014).

To measure the perceived robustness, experts were asked to rate the robustness of the product based on four different elements: its appearance and sounds during usage, the solidness/firmness of its design; the solid feel of buttons; and the weight of the product. the following four criteria were formulated. The criteria were measured on scales adapted to the product category (e.g., the wheels [of the vacuum cleaner] do not make a sound during usage and when shaken or moved heavily [and] feel solid and stable at normal use). The scales also considered the potentially negative associations of too heavy and 'tough' designs on consumers' preferences (e.g., for the weight a minimum and maximum were included for a high score). The exact scales per product category can be found in Deliverable 6.1 'Four draft specific testing programs'.

While testing the criteria in the lab, perceptions of what is robust sometimes differed between lab experts. What some experts perceived as robust was perceived differently by others. Especially the criteria about appearance, sound, and feel resulted in diverse scores. For example, some lab experts perceived a heavily turning knob of a washing machine as robust, while a knob with a ticking sound was perceived as robust by others. After consultation with the lab experts, we concluded that more precise and concrete scales per criterion are needed. For example, the exact tolerances of buttons and between components can be measured by the lab experts with their measuring equipment, for which the boundaries should be predefined in scales. To do so, we recommend to set-up consumer pre-tests in the lab in which these scales can be defined based on how on average consumers perceive specific tolerances for a product category. Also, reference products (or components) can be provided to the lab experts to ensure a clear reference point for assessment.

Another recommendation is to conduct the perceived robustness tests twice, that is before and after the reliability tests of WP3, in order to check if any differences can be found. Especially for sound, the lab experts expected to find relevant differences after extensive product usage. For example, louder sounds can emerge due to cylindric aging of washing machines, which can negatively affect the product value over time, and therefore trigger premature replacement. Measuring such sounds before and after the reliability tests would be especially relevant for washing machines and vacuum cleaners that have moving parts in their design, and thus less for smartphones and TVs.

While measuring the products' weight, no issues were reported by the lab experts. However, we acknowledge that this criterion needs further development as well. In the testing program, the weights labelled as either high or low robust were estimated based on desk research. We determined these measurements by ensuring the product was not too light (i.e., perception of low reliability) or too heavy (i.e., impacting the usability of the device). If this criterion is included in future testing programs, we recommend first conducting additional

consumer research in order to confirm what weights are considered robust, and based on that, determine the proper size/weight ratio per product.

2.7.4 Circular business models

Circular business models are considered key levers for the implementation of a circular economy. Circular business models can be defined as 'business models that are cycling, extending, intensifying, and/or dematerializing material and energy loops to reduce the resource inputs into and the waste and emission leakage out of an organizational system. This comprises recycling measures (cycling), use phase extensions (extending), a more intense use phase (intensifying), and the substitution of products by service and software solutions (dematerializing)' (Geissdoerfer, Pieroni, Pigosso and Soufani, 2020).

Initially, one of the proposed criteria in the user and market-aspects part of the testing programme was related to new business models. Specifically, a criterion linked to alternative business models and more precisely alternative ownership models focusing on extending product lifetime was proposed. The criterion consisted of one item: Does the brand offer alternative business models by keeping ownership of the product and thus stimulate long product lifetimes? Binary responses consisted of 'Brand offers leasing or pay-per-use models (i.e., manufacturers keep ownership of the product), consumer pays only for usage' vs. 'Brand does not offer alternative business model(s) that focus on product lifetime extension'.

Alternative ownership models, in which consumers gain access to the product but do not automatically own the product (Edbring et al., 2016; Tukker, 2004, 2015) are proposed as new avenues to develop the circular economy. Some business models such as renting or pay-per-use are indeed likely to encourage the use of products that are physically durable, which makes these products less likely to fail prematurely (Bocken, Mugge, Bom & Lemstra, 2018). For example, BlueMovement by Bosch inspires consumers to obtain a subscription for various household appliances (e.g., washing machine, dryer, refrigerator) and pay a monthly fee for using them. Another example is Homie, which is a Dutch company offering pay-per-use services for household appliances.

Such product-service systems (PSS) may result in longer product lifetimes as a result of several changes in product use. Durable appliances are usually pricier to purchase and alternative ownership models enable consumers to afford these appliances without having to spend the initial purchase price. From the manufacturer's perspective and as mentioned above, durable products are more likely to be selected for these PSS as less repair and replacement costs are involved when the products do not fail. In addition, these PSS may enhance repair when it is needed because the company is responsible for keeping the products functioning and will thus try to repair the product (over replacing it) to keep their costs as low as possible. The longer a product can be used, the more profit will be obtained from the subscription. Finally, when consumers terminate the subscription contract, the product can have a second (and third etc.) life via another customer subscription, thereby preventing the premature obsolescence of the product.

While this testing criterion was determined feasible by lab experts, its desirability was questioned. While they could easily find information about these alternative business models, the lab experts argued that these new business models did not intrinsically ensure that product lifetime would be extended. As a result, they concluded that this criterion was not a good candidate for a testing programme on premature obsolescence. Due to time and budget constraints, it was not possible to test a different formulation for the criterion, and the availability of alternative business models was removed from the current version of the testing programme. Yet, as these business models are clearly valuable for the development of a circular economy, we would like to formulate a few recommendations about the formulation of this criterion for the next version / an extension of the testing programme.

To prevent the use of alternative business models in a suboptimal way that does not reduce overall consumption levels (e.g. models that would stimulate consumers to replace their product too early to enjoy a newer model), we would like to recommend specifying further the criterion by including concrete incentives for both companies and consumers to extend the products lifetimes. First, specifying that the alternative business models should have a financial incentive for consumers to keep their products longer is likely to improve the likelihood that the models increase product lifetime. This could for example be shaped as a decreasing

subscription fee as the product gets older. Second, repair and maintenance aspects should be stipulated further and the alternative business models should include free repairs and support for maintenance, as well as the free replacement of parts that can be considered consumables (such as screen protectors and batteries for smartphones). Third, an aspect could be related to the fact that the products provided by the companies in the context of these business models should not necessarily be new, thereby encouraging companies to extend the number of lifecycles for their products and to use processes such as refurbishment. By including these aspects in this testing criterion, it is possible to ensure that the alternative business models are used in a way that extends product lifetimes.

2.7.5 Brand communication regarding product lifetime and free extended warranties

For Brand communication regarding product lifetime and free extended warranties the conduction of the test was not a problem. Some of the information are hard to find. Communication on product lifetime is not established.

2.8 Feasibility

To create a successful test programme, it must exhibit several characteristics: reliability, repeatability, relevance and feasibility. A new developed test programme will only be established if many stake holders have the potential to use it. Therefore, the rounded costs of the validation tests are presented here:

Table 2: Costs of PROMPT validation tests

Product category	Reliability	Repairability	User & Market Aspects	Samples	Number of samples
Washing machines	258.000 €	12.000 €	Incl. in reliability	43.000 €	90
Vacuum cleaner	60.000 €	13.000 €	3.500 €	24.000 €	56
Smartphone	50.000 €	10.000 €	Incl. in reliability	43.000 €	70
TV	56.000 €	13.000 €	Incl. in reliability	46.000 €	42

During PROMPT 5 Models of each product category were tested. Two of the selected models were also tested again in a second lab to investigate the reliability of the methodology. In summary, the reliability costs are high and extend the budget of a common product test at a consumer organisation by far. Repairability costs are acceptable and lower than expected. Similar applies for the user & market aspect costs. Considering rising energy costs and inflation the costs especially for cyclization and climate chamber tests will rise.
The testing time is another constraint. Especially aging/wear out tests take a long time. Testing times of approximately one year led to significant loss of impact of the published results. Fast market cycles result in a obsolescence of the test results for the consumer product purchase, if the results are published with a big time lag to the market entry of a product.
The lab capacities for the newer testing approaches for repairability and user & market aspects were high and of minor concern. The capacities for the cyclization of washing machines and accelerated aging in a climate chamber were rather rare. For the testing of the TVs big climate chamber were needed. They are in duty but often not available. Also, the long testing time was a challenge because the long-blocked time frame for the climate chambers.
In conclusion the most challenging part of the general test programme regarding feasibility are the reliability tests. Those tests are expensive and time consuming, additional for some test also the lab capacities are rare. Stakeholder like consumer organisations will not be able to adapt the full test programme. Still the tests are significant and important. Thus, a regulation to conduct this kind of tests and publish the results would be meaningful.

3 Conclusions

3.1 General Conclusions

In the PROMPT Project a suitable test programme for longevity was developed. Important criteria were identified. Test strategies and approaches were condensed in the general test programme. The general test programme is available to provide a basis for the development of product specific longevity test programmes for every kind of electrical and electronic equipment. PROMPT proofed, that a development of a suitable test programme for longevity of certain products is possible. It is possible to perform a series of tests to determine which product has a higher probability to last longer, considering reliability, repairability and user & market aspects. What the test programme cannot provide is an exact calculation of expected product lifetime in years or cycles. This kind of information would be highly valuable, because its easy comparable and understandable for the consumer. But it is influenced by a bunch of circumstances (environment, usage scenario, maintenance, mindset of the user, …), which is hardly condensed in one scenario because of its wide range of possible settings.
The performed lab tests in work package 6 revealed a high effort in time and budget. Some practical tests took approximately one year of automized testing (for example battery testing of smartphones). The long testing time leads to the problem of the big difference of the publication of results compared to the market entrance of a product. For most products (product cycles of approximately one year) a one-year testing time is not acceptable, because the information will be outdated and has limited influence on the purchase by the consumer. A high acceleration of the testing seems not to be possible at the moment for most of the long-term tests.
Besides the practical lab tests also gathering all necessary information was elaborate and is prone to mistakes. Certain information is provided by the manufacturer but hard to find or it is outdated. A standardized way of providing all necessary information (see questionnaire in appendix 4.1) what be highly desirable. A digital product passport could include all needed information and would be an easily accessible and trustful source for the consumers.
In conclusion the testing for longevity of products is possible and the developed general test programme is a suitable starting point to develop product specific test programmes. But the high effort impedes a broad adaptation of the general test programme in the regular product testing of consumer organizations. Similar also applies for market surveillance organisations. Manufactures have to provide information (product design, support/repair information) and even test results supplied by third party entities (standardized template, Information & test results) to consumers. Consumers are then able to identify long lasting products and make informed decisions.

3.2 Outlook/recommendations

The European Commission adopted a Circular Economy Package including a proposal for a "Regulation on Ecodesign for Sustainable Products", pushing for Ecodesign to systematically introduce reliability and repairability requirements and to extend these measures to more product categories. The development and improvement of Ecodesign requirements can set minimum environmental requirements that products must comply with to be placed on the EU market. The results of PROMPT can feed into this process by identifying relevant criteria and suitable methodologies and tests.
There is a big need for standardized tests for reliability, repairability and user & market aspects. Standardized tests will enable a proper comparison of different products, easier communication to the consumer and decrease testing costs. Starting with the general test programme of PROMPT, test programmes for further product categories can be developed.
The needed budget and time for this extensive testing leads to of consumer organisations. Thus, the manufacturer must provide the necessary information and test results. An integration in the product passport would be a smart solution. The tests should be performed by independent certified laboratories.
Furthermore, a publicly available failure rate database (based on consumer feedback, manufacturer data, repair statistics) would help to identify problematic components of certain product categories. And thus enable the development of a component centred new test. An integration of a failure messaging system in the product

passport would be a smart solution. The gathered data can be used to create, update and verify the priority part list.
From a research perspective a detailed study on different diagnosis mechanism on different product categories would be helpful to improve the diagnosis assessment methodology. For the eDim methodology more data is needed to improve the calculated proxy times.

4 Appendix

4.1 Questionnaire

1	**Reliability**
1.1	*Maintenance*
1.1.1	Are there any online videos or step by step guides for maintenance provided by the manufacturer? [yes, no]
1.1.1.1	If yes, please specify step by step guides for maintenance! [video guide for filter cleaning, step by step guide for updates, …]
1.1.1.2	If yes, where are the supporting information for maintenance available (link to manufacturers website) [please specify]
1.1.1.3	*Comment (step by step guides for maintenance)*
1.1.2	Does the manufacturer offer cleaning supplies for consumers? [detergents, cloth, …]
1.1.2.1	If yes, please specify the cleaning supplies!
1.1.2.2	If yes, where are the cleaning supplies available (link to manufacturers website or shops)? [please specify]
1.1.2.3	*Comment (cleaning supplies)*
1.1.3	Does the manufacturer offer protective supplies for consumers? [protective covers/films, anti-theft system, …]
1.1.3.1	If yes, please specify the protective supplies!
1.1.3.2	If yes, where are the protective supplies available (link to manufacturers website or shops)? [please specify]
1.1.3.3	*Comment (protective supplies)*
1.1.4	Does the manufacturer offer consumables for consumers? [filters, batteries, dust bags, …]
1.1.4.1	If yes, please specify the consumables!
1.1.4.2	If yes, where are the consumables available (link to manufacturers website or shops)? [please specify]
1.1.4.3	*Comment (consumables))*
1.2	*Updates*
Definition	A software update is a process of maintenance and ensures the functionality of a product. This could include for example: fixing of programming errors, updated databases, closing of security gaps. Processes adding new functionalities or aesthetics or leading to a major increase of performance or capacity of a product are considered an upgrade (see below).
1.2.1	What is the guaranteed period for availability of firmware updates since market launch of the product? [years]
1.2.1.1	Where to find an official and publicly available statement on the guaranteed period for availability of firmware updates (manual pages, link to manufacturer website)? [please specify]
1.2.1.2	*Comment (firmware updates)*
1.2.2	What is the guaranteed period for availability of security updates since market launch of the product? [years]
1.2.2.1	Where to find an official and publicly available statement on the guaranteed period for availability of security updates (manual pages, link to manufacturer website)? [please specify]
1.2.2.2	*Comment (security updates)*

1.2.3	What is the guaranteed period for availability of software updates since market launch of the product? [years]
1.2.3.1	Where to find an official and publicly available statement on the guaranteed period for availability of software updates (manual pages, link to manufacturer website)? [please specify]
1.2.3.2	*Comment (software updates)*
2	**Repairability**
2.1	*Availability of repair information*
2.1.1	Is there a **component identification code** on the priority parts?
2.1.1.1	Component code on the priority part 1l?
2.1.1.2	*Comment (Component code)*
2.1.2	Is there a **step by step replacement guide** for the priority part provided by the manufacturer (online or physical) for **consumers**?
2.1.2.1	SbS guide Consumer for the priority part 1
2.1.2.2	*If yes, please provide the link or the manual pages on consumer step by step replacement guide*
2.1.2.3	SbS guide Consumer for the priority part 1 source
2.1.2.4	*Comment (step by step replacement guide consumers)*
2.1.3	Is there a **step by step replacement guide** (SbS guide) for the priority part provided by the manufacturer (online or physical) for **independent professional repairer**? [yes, no]
2.1.3.1	SbS guide professionals for the priority part 1
2.1.3.2	*If yes, please provide the link or the manual pages on professionals step by step replacement guide*
2.1.3.3	Step by SbS guide professionals for the priority part 1 source
2.1.3.4	*Comment (Step by step replacement guide profesionals)*
2.1.4	Is there a **video replacement guide** for the priority part provided by the manufacturer (online) for **consumers**? [yes, no]
2.1.4.1	video replacement guide consumers for the priority part 1
2.1.4.2	*If yes, please provide the link on consumer video replacement guide*
2.1.4.3	video replacement guide consumers for the priority part 1 source
2.1.4.4	*Comment (video replacement guide consumer)*
2.1.5	Is there a **video replacement guide** for the priority part provided by the manufacturer (online) for **independent professional repairer**? [yes, no]
2.1.5.1	video replacement guide professionals for the priority part 1
2.1.5.2	*If yes, please provide the link on professionals video replacement guide*
2.1.5.3	video replacement guide professionals for priority part 1
2.1.5.4	*Comment (video replacement guide professional)*
2.1.6	Is there a description of the **level of skills** required to repair the product (online or physical)? [yes, no]
2.1.6.1	If yes, please provide the link or the manual pages on level of skills
2.1.6.2	*Comment (level of skills)*
2.1.7	Is there a description of the **working environment conditions** needed to repair the product (online or physical)? [yes, no]
2.1.7.1	If yes, please provide the link or the manual pages on working environment conditions
2.1.7.2	*Comment (working environment conditions)*
2.1.8	Is there a description of the **number of persons** required to do the repair the product (online or physical)? [yes, no]

2.1.8.1	If yes, please provide the link or the manual pages on number of persons
2.1.8.2	*Comment (number of persons)*
2.1.9	Is there a **list of tools** needed for repair (online or physical)? [yes, no]
2.1.9.1	If yes, please provide the link or the manual pages on list of tools
2.1.9.2	*Comment (list of tools)*
2.1.10	Is there any information on **safety risks** that the repairer may be exposed to during the repair? [yes, no, not applicable]
2.1.10.1	If yes, please provide the link or the manual pages on safety risks
2.1.10.2	*Comment (safety risks)*
2.1.11	Is there a **parts list** available provided by the manufacturer (online or physical) for **consumers**? [yes, no]
2.1.11.1	If yes, please provide the link or the manual pages on part list for consumer
2.1.11.2	*Comment (part list consumer)*
2.1.12	Is there a **parts list** available provided by the manufacturer (online or physical) for **independent professional repairer**? [yes, no]
2.1.12.1	If yes, please provide the link or the manual pages on part list for professional
2.1.12.2	*Comment (part list professional)*
2.1.13	Is there an **exploded view** available provided by the manufacturer (online or physical) for **consumers**? [yes, no]
2.1.13.1	If yes, please provide the link or the manual pages on exploded view for consumers
2.1.13.2	*Comment (exploded view consumers)*
2.1.14	Is there an **exploded view** available provided by the manufacturer (online or physical) for **independent professional repairer**? [yes, no]
2.1.14.1	If yes, please provide the link or the manual pages on exploded view for professionals
2.1.14.2	*Comment (exploded view professionals)*
2.1.15	Are **spare parts for a priority part** provided by the manufacturer for **consumers**? [yes, no]
2.1.15.1	spare parts for the priority part 1 for consumers
2.1.15.2	If yes, please provide the link or the manual pages on spare parts for consumers
2.1.15.3	*Comment (spare parts for consumers)*
2.1.16	Are **spare parts for a priority part** provided by the manufacturer for **independent professional repairers**? [yes, no]
2.1.16.1	spare parts for the priority part 1 for professionals
2.1.16.2	If yes, please provide the link or the manual pages on spare parts for professionals
2.1.16.3	*Comment (spare parts for professionals)*
2.1.17	What is the guaranteed **period for availability of spare parts** for priority parts since market launch of the product? [years]
2.1.17.1	Where can information regarding guaranteed period for availability of spare parts for priority parts since market launch be found? [website, manual page]
2.1.17.2	*Comment (period for availability of spare parts)*
2.1.18	What are the **costs of spare parts** for priority parts? [Euro]
2.1.18.1	costs of spare part for the priority part 1
2.1.18.2	*Comment (costs of spare parts)*
2.1.19	Is there a list of **recommended retail prices** (public) for spare parts? [yes, no]
2.1.19.1	If yes, please provide the link or the manual pages on the list of recommended retail prices
2.1.19.2	*Comment (recommended retail prices)*

2.1.20	Is there a list of **recommended repair costs** of priority parts? [yes, no]
2.1.20.1	If yes, please provide the link or the manual pages on recommended repair costs
2.1.20.2	*Comment (recommended repair costs)*
2.1.21	Does the **manufacturer** provide a **repair service**? [yes, no]
2.1.21.1	If yes, please provide the link or manual page on manufacturers repair service
2.1.21.2	*Comment (manufacturer repair service)*
2.1.22	Where can information regarding repair **voiding warranty** be found? [website, manual page]
2.1.22.1	Does a repair, done by a consumer, void warranty? [yes, no]
2.1.22.2	Does a repair, done by an independent professional repairer, void warranty? [yes, no]
2.1.22.2	Does a repair, done by authorized repair service provider, void warranty? [yes, no]
2.1.22.3	*Comment (repair voiding warranty)*
2.1.23	Is it the **warranty information** available in the official local language (in the manual and internet site)? [yes, no]
2.1.23.1	If yes, please provide the link or manual page on local warranty information
2.1.23.2	Is the warranty information available in English (in the manual and internet site)? [yes, no]
2.1.23.3	If yes, please provide the link or manual page on english warranty information
2.1.23.4	*Comment (warranty information)*
2.2	*Diagnosis*
2.2.1	Is there any **error message or indication** when the product is damaged? [yes, no]
2.2.1.1	If yes, please specify the kind of error message (multiple answers possible, for example: error code, led indicator, acoustic signal)
2.2.1.2	After the repair is complete, is there an manual on how to **remove the error message**? [yes, no]
2.2.1.3	If yes, please provide the link or the manual pages
2.2.1.4	Is an **error code database** available for consumer? [yes, no]
2.2.1.5	If yes, please provide the link or manual pages.
2.2.1.6	*Comment (error code database)*
2.2.2	Is additional **diagnosis software or hardware** provided by the manufacturer for consumers? [yes, no]
2.2.2.1	If yes, please specify the kind of diagnosis tools.
2.2.2.2	Is additional diagnosis software or hardware provided by the manufacturer for independent repairer? [yes, no]
2.2.2.3	If yes, please specify the kind of diagnosis tools.
2.2.2.4	*Comment (diagnosis)*
3	**User and market aspects**
3.1	*Upgrades*
Definition	An upgrade is a process of increasing the functionality, performance, capacity or aesthetics of a product and may involve changes to its software, firmware and/or hardware.
3.1.1	Are there any measures in the product design and specifications to equip/facilitate **future aesthetic upgrades**? [yes, no]
3.1.1.1	If yes, please specify these measures!
3.1.1.2	*Comment (designed for aesthetic upgrades)*
3.1.2	Are there any measures in the product design and specifications to equip/facilitate **future functional, performance or capacity upgrades** of the product (fasteners, interfaces)? [yes, no]

3.1.2.1	If yes, please specify! (measures to equip/facilitate functional, performance or capacity upgrades)
3.1.2.2	*Comment (functional, performance or capacity upgrades)*
3.1.3	Are **aesthetic upgrades** currently available by the manufacturer? [yes, no]
3.1.3.1	If yes, please specify! (aesthetic upgrades)
3.1.3.2	*Comment (aesthetic upgrades)*
3.1.4	Are **functional, performance or capacity upgrades** currently available by the manufacturer? [yes, no]
3.1.4.1	If yes, please specify! (functional, performance or capacity upgrades)
3.1.4.2	*Comment (functional, performance or capacity upgrades)*
3.2	*Brand policy*
3.2.1	Circular business models
3.2.1.1	Are there any **alternative business models** for consumers offered by the manufacturer by keeping ownership of the product? [yes/no]
3.2.1.2	If yes, please specify! (alternative business models)
3.2.1.3	Where to find information regarding alternative business models (manual page, link to manufacturers website)? [please specify]
3.2.1.4	*Comment (alternative business models)*
3.2.2	Free extended warranty
3.2.2.1	Is a **free extended warrantee** beyond the legal regulations offered by the manufacturer? [yes/no]
3.2.2.2	What is the valid period of the extended warrantee? [years]
3.2.2.3	Are there parts/components orddamages are excluded from the extended warrantee?
3.2.2.3	What parts/components or damages are excluded from the extended warrantee? [please specify]
3.2.2.4	Is a registration of the product mandatory to qualify for the free extended warrantee? [yes/no]
3.2.2.5	where to find information regarding free extended warrantees (manual page, link to manufacturers website)? [please specify]

4.2 Disassembly assessment – additional information

4.2.1 Disassembly template

The following picture shows the head of the provided excel file to record the disassembly actions:

Lab entry																				
Product ICRT Code	**Brand**	**Model name**	**Priority part name**	**Disassembly Sequence**	**Phase of action**	**Component Being removed**	**Tool used** (leave blank no tool is used)	**Tool type**	**Action**	**Force / Intensity**	**Identifiability**	**component/fastner is seperated and placed aside (not the tool)**	**Repetitions (1+)**	**product manipulation (Tilt / Flip) (1/0)**	**Tool positioning (obstructed or d<3mm) (1/0)**	**Connected action to above (1/0)**	**Fastner Reuasbility**	**Additional Positioning required during Reassembly**	**Repair Saftey Hazard**	**Actual (Recorded) Disassembly time (s)**	**Actual (Recorded) Reassembly time (s)**	**Comments (If any)**

Most of the columns have a drop-down menu with predefined content, which simplifies the correct completion of the disassembly file. The following table summarizes information and support to fill out the disassembly file.

Data	**Information**	
Disassembly Sequence	Sequence followed during disassembly to remove all the priority parts form the product. The end of disassembly takes place once all the priority parts are removed. If a priority part cannot be separated due to non-removable fastener (see fasteners type), the disassembly step is noted until non removable fastener is encountered. If a priority part is permanently attached to another functionally independent component, the attached component should be less than 50% (in weight) smaller than the priority part being removed to be considered "removable". If two priority parts are attached to each other permanently, both priority parts are considered non removable.	
Component being removed	Any component being removed. A fastener by itself is not considered a component.	
Tool Used	Specific Tool used during the disassembly action (e.g. Philips 00)	
Action	Turn (screw, thread) x turn	Any turn action recorded with number of turns. E.g. turning screws with screwdriver, turning knobs or hose by hand to loosening it.
	Pry (snap fit, Adhesive)	Any pry action to widen a gap or detach attachment. (E.g. For snap fits, loose adhesives and some friction fit)
	Remove (Lift, friction fit)	Removing/lifting a component that is placed on its own weight or via friction fit. This also includes lifting/removing weights from washing machine
	Pull (tab, peel)	Pull or peel action. E.g., peeling sticker, pulling component, pulling a hose or cable plug out straight (that is not held by lever or side clicks). If peeling tab also requires turning, this pull action could be combined with turn action. (see "connected actions")
	Disconnect (cable plug, hose, buttons)	Disconnecting hose or cables that have click mechanism that needs to be pressed or lifted before disconnection (e.g. Vacuum cleaner hose, electronic cables in PCB)
	Push (buttons, components)	Push button or push components
	Strike	Connectors requiring short up-down tapping/striking motions (e.g. Nails, washing machine bearings)
	Cut (plier, scissor, knife)	Surfaces, wires and tighteners, cables etc. to be cut using pliers, knife or scissors
	Adhesive (heat/Alcohol)	Heating or Using alcohol to loosen adhesive (Note. Pry or remove action is still required afterwards). Waiting or heating for 30 seconds is considered. If additional heating/waiting is required, this action is repeated.

	Crank (bolt)	Any arc motions. One crank= full motion back to starting point. E.g., cranking bolt using wrench.
	Pry circumference (per 5 cm)	Prying entire circumference 5+cm of a cover or assembly held on by (e.g.) adhesive, snap fit or friction fit. For example, prying around phone display, or TV cover. Note. Every addition of 5 cm of prying adds 1 unit in "repetition" tab.
	Complex manipulation (unthread)	Any complex action not covered by any of the other actions. E.g. Unthreading cables. Less than 5 times arm/hand movement = low force, 5-10 times = medium force, 10+time = high force
	Hinge (open door, hinged cover)	opening actions for components that are hinged, (e.g., door or hinged cover)
	Place (suction cup, reposition)	Placement of a additional tool to assist disassembly or placement of a component after lifting it to reposition it.
Force Intensity	Low (finger ,0-5N)	Light force used (5-20N), mainly wrist/hand action
	Medium (Wrist, 5-20N)	Moderate force used (5-20N), mainly wrist/hand action
	High (Arm, 20+N)	Moderate force used (20+N), mainly arm or both hand action
	Note. some actions have exceptions (e.g. Adhesives) these are specifically stated	
Tool Type	Hand	Only hand used
	Class A	Class A tools as classified in standard EN45554. If a tool is provided with the product (e.g., sim card ejector) it is considered Class A. Furthermore, the following tools are classified as Class A tools: • screwdrivers with flathead (slot drive), cross recess (Phillips, Pozidrive), or hex lobular recess (Torx) head (all sizes) • Hexagon socket keys in commonly used sizes • Combination wrench • Combination pliers • Half round nose pliers • Diagonal cutters • Multigrip pliers • Locking pliers • Combination pliers for wire stripping and terminal crimping • Prying lever (including variants such as spudger, and opening tool) • Tweezers • Hammer • Utility knife with snap-off blades • Multimeter • Voltage tester • Soldering iron • Hot glue gun • Magnifying glass
	Class B	Product group specific Class B tools as classified in standard EN 455554. Class B tools are tools which are not considered Class A and are publicly available and are needed for repairing products produced by at least two different manufacturers.

	Class C	Class C tools as classified in standard EN 455554. Other tools that are commercially available not classified as class A or B.
	Class D/E	The product cannot be disassembled using any commercially available tools. Class D & E tools as classified in EN45554 standard. Class D tools are proprietary tools and Class E corresponds to not existing tools.
Visibility	Visible (>0.5mm)	more than 0.5 mm2 of unobstructed visibility on area of action when looked perpendicular to the plane of action
	Not visible (< 0.5mm)	less than 0.5mm2 of area of action is visible when looked perpendicular to the plane of action
component/ fastener is separated and placed aside	The component or a fastener gets separated during the action performed (without the removal action) and can be placed aside. E.g., unscrewed screws placed aside, prying open vacuum cleaner housing separates the housing instantly and is placed aside.	
Repetitions	Number of repetitions of same action during the same sequence (e.g., unscrewing 5 same type screw, is 5 repetitions). (By default, this is set to 1)	
product manipulation (Tilt / Flip)	The product needs to be tilted or flipped for action to be performed. (e.g., tilting vacuum cleaner to reach underside). (By default, this is set to 0)	
Tool/component positioning obstructed	the area of action for tool to be positioned is less than 3 mm2 due to its size or is obstructed.	
Connected action to above	If two or more actions must be done simultaneously then this feature could be used. E.g., placing suction cup & prying while pulling the disassembly screen.	
Fastener Reusability	Reusable fastener	Any fastener that are designed be reused without damaging the product. (e.g. Screws and non-breakable snap fits)
	Removable but not reusable	Fastener that breaks during disassembly or reassembly but is still removable without damaging the product. (e.g., heat weakening adhesive, zip ties). Note. Breakable Snap fits that are part of a component (e.g., in housing), are non-removable.
	Non removable	Any fastener that damages the product or its component during its disassembly or reassembly. (e.g. Breakable snap fits, soldered or welded parts).
Additional Positioning required during Reassembly	Additional positioning is required to place the component during reassembly. This could be due to the component being obstructed, needs to be held together precisely, or needs to be placed carefully before it can be fastened.	
Repair Safety Hazard	If the Acton presents any safety hazard to the user as according to PROMPT safety framework. (By default, this is set to NONE)	
Actual disassembly and reassembly time	Actual time taken for disassembly and reassembly of each action. NOTE. This is required for verification and calibration process; this will not be present in the final testing program.	
Comments	If there are any comments related to disassembly, testing methodology or the product.	

4.2.2 Safety hazard assessment

4.2.2.1 Introduction

This document serves as a guideline for test laboratories when testing appliances within the framework of the test methods developed in the PROMPT project (https://prompt-project.eu/).
It presents a method to assess safety risks arising during the disassembly and reassembly of electrical products, based on material properties of the product. Certain physical characteristics of the product (such as sharp edges or voltage carrying components that could be touched during repair) can exacerbate repair-related safety risks, whereas others (such as keyed wire connections or visible assembly cues) can mitigate them.
The risk of injury either during or after repair is assessed based on two factors: the likelihood of an incident occurring, and the severity of the consequences if an incident occurred.
The likelihood of an incident occurring is evaluated in the following tiers:

Table L: Likelihood of incident

N	Not possible
XL	Extremely low likelihood
L	Low likelihood
M	Medium likelihood
H	High likelihood

The severity of the consequences should an incident occur is evaluated in the following tiers:

Table S: Severity of incident

N	No injury
L	Low severity: pain but no incapacity to work
M1	Medium 1 severity: incapacity to work for less than 1 week (e.g. small cuts or burns)
M2	Medium 2 severity: incapacity to work for more than 1 week (e.g. broken finger, 3rd degree burn,...)
H	High severity: lethal consequences or permanent disability (e.g. loss of limb, sight,...)

The combination of these two parameters results in an aggregated risk level ranging from A (very low likelihood and/or severity, resulting in negligible risk) to F (high likelihood and severity, resulting in highest total risk), according to the following table:

Table A: Aggregated risk level

	Severity				
Likelihood	N	L	M1	M2	H
N	A	A	A	A	A

XL	A	A	A	B	C
L	A	B	C	C	D
M	A	C	C	D	E
H	A	C	D	E	F

The following document provides guidance on how to assign relevant likelihood and severity levels, and resulting aggregated risk level, to incidents that might happen during or after repair of electrical appliances, considering risks that are electrical, thermal or mechanical in nature.

4.2.2.2 General procedure

For each repair process (i.e. the replacement of each priority part starting from the appliance in fully assembled state), the disassembly tree is investigated to look for 'hot spots' i.e. operations that might create an electrical, thermal or mechanical risk during or after the repair. For each of the operations identified as involving a risk, the likelihood and severity of potential incidents are evaluated based on the explanations and tables below. This results in a risk level ranging from A to F assigned to the repair process. It is proposed that the total risk level of the repair process is based on the highest risk of any operation that is part of the process under investigation. Consequently, only the step that is identified as the most hazardous needs to be assessed according to this procedure. This significantly reduces the time and complexity of the safety assessment. Results may be further aggregated, for example to assign a general repair risk score to a product as a whole. The result of the risk assessment may be used to differentiate between products that are safer or less safe to repair. It may also lead to recommendations concerning the skill level required to deal with the risks involved; for instance, as far as electrical risks are concerned, certain repair operations on certain appliances may require either an electrically instructed person or an electrically skilled person as defined by preventive standards such as the ones issued by the German Social Accident Insurance (DGUV).

4.2.2.3 Electrical hazards during repair

Likelihood

The likelihood of exposure to electrical voltage is determined based on three factors: whether the part that carries a voltage is shielded or can be touched with a finger or a tool respectively, the presence of warning labels, and the persistence of a hazardous voltage (see table E.2.) after the appliance has been unplugged for one minute (as can be the case with capacitors for instance).

Table E1: Likelihood of exposure to electrical current

Possible contact			Persistence of voltage		Warning label		**Likelihood class**
None - no contact possible	Tool (e.g. screwdriver) cf. IEC 61032 test probe 13 (3x15mm)	Finger cf. IEC 61032 test probe B (12x80mm)	voltage present only when plugged in	voltage present 1 min after unplugging	present	absent	
X					X		**N**

X						X	**N**
	X		X		X		**XL**
	X		X			X	**L**
	X			X	X		**XL**
	X			X		X	**M**
		X	X		X		**L**
		X	X			X	**M**
		X		X	X		**M**
		X		X		X	**H**

Severity

The severity of the consequences of exposure to electrical voltage is determined based on the magnitude of the voltage, with reference to the levels of voltage that are considered safe on average depending on the skin conditions according to Belgian electrical regulations *Algemeen Reglement op de elektrische installaties (AREI)*art. 31.03.

Table E2: Severity of exposure to electrical current

Voltage present				
Alternating current	Direct current with ripple	Direct current without ripple	hazard level	**severity class**
0V	0V	0V	no hazard	**N**
>0V <25V	>0V <36V	>0V <60V	safe level for wet skin	**L**
>25V <50V	>36V <75V	>60V <120V	safe level for dry skin	**M1**
>50V	>75V	>120V	hazardous even with dry skin	**H**

The aggregated risk level can be found by looking up the combination of the applicable likelihood and severity classes in table A.

4.2.2.4 Thermal hazards during repair

Likelihood

The likelihood of incidents due to exposure to high temperatures is determined based on three factors: the proximity of the heat source to the operator during the repair, the presence of warning labels and the persistence of hazardous temperatures (see table T.2.) after the appliance has been unplugged for one minute.

Table T1: Likelihood of exposure to high temperatures

protection of hot part		heat dissipation after unplugging		proximity to hot part			warning label		**Likelihood class**
insulated /shielded	none	<1min	>1min	contact	<15cm	>15cm	present	absent	
X									**XL**
	X	X				X	X		**L**
	X	X				X		X	**L**
	X	X			X		X		**L**
	X	X			X			X	**L**
	X	X		X			X		**L**
	X	X		X				X	**M**
	X		X			X	X		**M**
	X		X			X		X	**M**
	X		X		X		X		**M**
	X		X		X			X	**H**
	X		X	X			X		**H**
	X		X	X				X	**H**

Severity

The severity of the consequences of exposure to heat is determined based the temperature of the heat source that the repairer may come in contact with (referring to the thresholds for pain, reversible and non-reversible injuries as defined in ASTM C1055, *Standard Guide for Heated System Surface Conditions that Produce Contact Burn Injuries*), the expected duration of exposure, and the area of the skin that is likely to be affected. N.B. The affected skin area is determined by the exposed hot surface and/or the quantity of hot liquid or other media that might be released during the repair operation.

Table T2: Severity of exposure to high temperatures

temperature			exposure time			skin area affected			**Severity**
<45°	>45° <60°	>60°	<2 sec	>2 sec <5sec	>5 sec	<5cm2	>5cm2 <100cm2	>100cm2	
X			X			X			L
X			X				X		L
X			X					X	L
X				X		X			L
X				X			X		L
X				X				X	L
X					X	X			L
X					X		X		L

X					X			X	L
	X		X			X			L
	X		X				X		L
	X		X					X	L
	X			X		X			M1
	X			X			X		M1
	X			X				X	M1
	X				X	X			M1
	X				X		X		M2
	X				X			X	M2
		X	X			X			M1
		X	X				X		M1
		X	X					X	M1
		X		X		X			M1
		X		X			X		M2
		X		X				X	M2
		X			X	X			M2
		X			X		X		H
		X			X			X	H

The aggregated risk level can be found by looking up the combination of the applicable likelihood and severity classes in table A.

4.2.2.5 Mechanical hazards during repair (sharp edges)

At this point, only mechanical hazards related to sharp edges are assessed; other mechanical hazards (such as crushing, impact etc.) may be considered in a later iteration of the assessment method.

Likelihood

The likelihood of incidents due to sharp edges is determined based on two factors: the proximity of the sharp edge to the operator during the repair, and the force applied by the operator during the repair operation under consideration.

Table M1: Likelihood of exposure to sharp edges

proximity to sharp edge			Force applied			**Likelihood class**
>15cm	<15cm	contact	low (fingers)	medium (forearm)	high (upper body)	
X			X			**XL**
X				X		**L**

X					X	**M**
	X		X			**L**
	X			X		**M**
	X				X	**H**
		X	X			**M**
		X		X		**H**
		X			X	**H**

Severity

The severity of the consequences of exposure to sharp edges is determined based on the force of the movement and the sharpness of the edge tested, notably whether it has a radius larger or smaller than 0.5mm and whether it cuts the test tape of a sharpness tester according to UL1439 (*Standard for Determination of Sharpness of Edges of Electrical Equipment*).
Note that the force applied thus plays a role both in the likelihood of an accident happening and in the severity of the consequences should an accident occur: the higher the force, the more likely the operator is to slip or have an uncontrolled movement causing him/her to come in contact with the edge, and the more serious the resulting injury.

Table M2: Severity of exposure to sharp edges

sharpness of edge			Force applied			**Severity class**
radius >0.5mm	radius <0.5mm	sharp (UL1439)	low (fingers)	medium (forearm)	high (upper body)	
X			X			**N**
X				X		**L**
X					X	**L**
	X		X			**L**
	X			X		**M**
	X				X	**M**
		X	X			**M**
		X		X		**H**
		X			X	**H**

The aggregated risk level can be found by looking up the combination of the applicable likelihood and severity classes in table A.

4.2.2.6 Post Repair Risk

Post repair risks are anticipated risks due to potential mistakes in reassembly. Based on Ingemarsdotter et al, 2021 "Design for Safe Repair in a Circular Economy", these risks can also be divided into electrical, thermal, and mechanical risks, as with risks occurring during repair.

Likelihood

The likelihood of incorrect reassembly is highly dependent on the product's design. According to Ingemarsdotter et al, 2021, design features facilitating the correct reassembly of a product and thus mitigating post-repair risks include:

- keying (the part can only fit one way);
- visual/auditory feedback during connection and visual cues;
- information in the product for reassembly.

Similarly, features hampering reassembly could offset features assisting reassembly and increase the likelihood for post repair risk. These features include:

- Hard to reach area for reassembly;
- Impaired visibility during reassembly.

The risk likelihood is therefore based on the number of these design features present in the product, with one facilitating feature reducing the likelihood by one grade, and 2 or 2+ facilitating features reducing the likelihood to a very low level. Similarly, design features hampering reparability increase the likelihood by one grade.

Table P1: Likelihood of post-repair incidents based on design features

Number of facilitating features	Number of hampering features	Total feature score	**Likelihood class**
0	0	0	**M**
0	1	-1	**H**
0	2	-2	**H**
1	0	1	**L**
1	1	0	**M**
1	2	-1	**H**
2	0	2	**XL**
2	1	1	**L**
2	2	0	**M**
3	0	3	**XL**
3	1	2	**XL**
3	2	1	**L**

Severity

The severity class of electrical, thermal and mechanical post-repair hazards is assessed in a similar way as for incidents during repair, taking into account the worst-case scenario for each type of incident.

Table P2: Severity of post-repair incidents

Risk Type	**Risk**		**Severity**
Electrical	Electrical shock due to leakage or improper connection (Assumption of shock will be above hazard levels)	safe voltage for wet skin (see table E2)	**L**
		safe voltage for dry skin (see table E2)	**M1**

		hazardous voltage even with dry skin (see table E2)	**H**
Thermal	Water: thermal burn due to hot liquid burst	temperature <45°	**L**
		temperature >45° <60°	**M2**
		temperature >60°	**H**
Thermal	Fire: thermal burn due to short circuit from leakage		**H**
Thermal	Fire: thermal burn due to short circuit from improper cable connection		**H**
Mechanical	Cut and injury due to improper installation of product (10-25Kg)		**M1**
Mechanical	Cut and toppling due to improper installation of product (>25Kg)		**H**

The aggregated risk level can be found by looking up the combination of the applicable likelihood and severity classes in table A.