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The French repairability index: feedback from the repair community

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Abstract

Each year tremendous amounts of waste from electronic and electric equipment, also referred as E-waste, are generated. The Global E-waste monitor reported the generation of 53.6 million tons of worldwide E-waste in 2019. Based on the current trend, the total weight of E-waste could reach 74 million tons by 2030. E-waste being partly composed of hazardous substances, its inadequate disposal represents a threat to people and ecosystems. In response to this alarming situation, governments take actions to encourage circular economy in order to decouple value production from waste generation. In this context, the French government came up with the French repairability index with the aim of guiding consumers towards products designed for repair and thus increasing repair tendencies. The contribution of the repair community is essential for the success of the French repairability index. This raises the question of how the index will affect the repair community and to what extent the index can be a guiding tool for repair. This study aims at clarifying these points with contributions from repairers from Repair Cafés, Fabrication Laboratories, Universities and professional organizations, collected through semi-structured interviews. The study notably reports the enthusiasm of the repair community regarding the establishment of the index. However, some adjustments may be required for the index to better reflect true repairability.

Contents

Introduction

The 2030 Agenda for sustainable development targets peace and prosperity for people and planet. Facing global warming, inequalities and numerous sociopolitical issues, the members of the United Nations reported 17 goals for sustainable development. The 1987 Brundtland report qualifies sustainable development as “a development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

To be part of sustainable development, our traditional economy needs to change. The current linear economy rests on three main consecutive actions: buy, use then throw away. This economy generates huge amounts of waste containing significant amounts of substances harmful to the environment and human health. The Global E-Waste Monitor reports millions of tons of electronic waste generated each year and foresees significant increase for years to come.

Many actions are taking place at the national and European levels to promote circular economy, which aims at maximizing products number of life cycles. Repair is one of circular economy pillars. Indeed, electronic products can be given new life cycles thanks to repair. However, repair is facing different barriers associated with repair cost, lack of information, consumption habits … Stating that only a minority of broken electronic devices are repaired, the French ministry for ecological transition introduced the French repairability index in 2021. The index aims to raise customers’ awareness regarding the repairability of electronic devices. Thus, steering consumers towards more repairable products and encouraging them to repair broken devices showing good index. The index should also encourage manufacturers to promote eco-conception.

Professional and voluntaries repairers represent another important stakeholder in the strategy implemented around the index. One may ask, can repairers use the index to quickly assess repairability of electronic devices and, therefore, help decide if they will carry out repair or not? In this work, interviews are conducted within the repair community to bring answers to this question.

This work is structured as follows. Chapter 1 starts by presenting the problematic of E-waste. The following sections give insights regarding repair and the foundations of circular economy. Chapter 2 introduces the French repairability index. This Chapter contains a literature review of the index and a comparison of the latter with other repair metrics such as the iFixit index. Finally, Chapter 3 details the data sample and the analysis resulting from the interviews.

Chapter 1. E-waste and repair

This first Chapter starts by exposing the problematics associated with electronic waste. The repair solution is then introduced in the framework of circular economy and sustainable development. This Chapter lists and describes some of the barriers to repair and some actions promoting repair. After that, it is shown, thanks to a Fermi computation, that repair cannot be the only solution to the electronic waste growth. Other paradigms must be considered to extend the life cycles or to give new life cycles to electronic objects. In that regard, this chapter concludes by recalling some of the principles of circular economy through the 7R's.

1.1 E-waste growth

Electrical and Electronic Equipment (EEE) designate all the products that include electrical components such as electrical circuitry, batteries or power supplies. EEEs have become omnipresent in our houses, industries and in our lifestyle. Nowadays, most people benefit from kitchen appliances, smartphones, electrical toys … Besides, EEEs are increasingly used in technology related applications such as in new generations of telecommunications systems, transport, or in energy supply systems. The intensive use of electronic devices and the fact that people currently live in a predominant linear economy characterized by three main steps: buy, use and throw away have led to important amounts of Waste from EEE (WEEE).

The Global E-Waste Monitor has reported around 53.6 million tons (Mt) of worldwide electronic waste in 2019, which represents an increase of 21% in 5 years (Forti et al, 2020). A geographical mapping illustrating the continental repartition of electronic waste generated in 2019 is provided in Fig. 1. In 2019, Asia was the first producer of WEEE with 24.9 Mt. America and Europe follow with 13.1 Mt and 12 Mt, respectively. Africa produced 2.9 Mt and Oceania was responsible for 0.7 Mt.

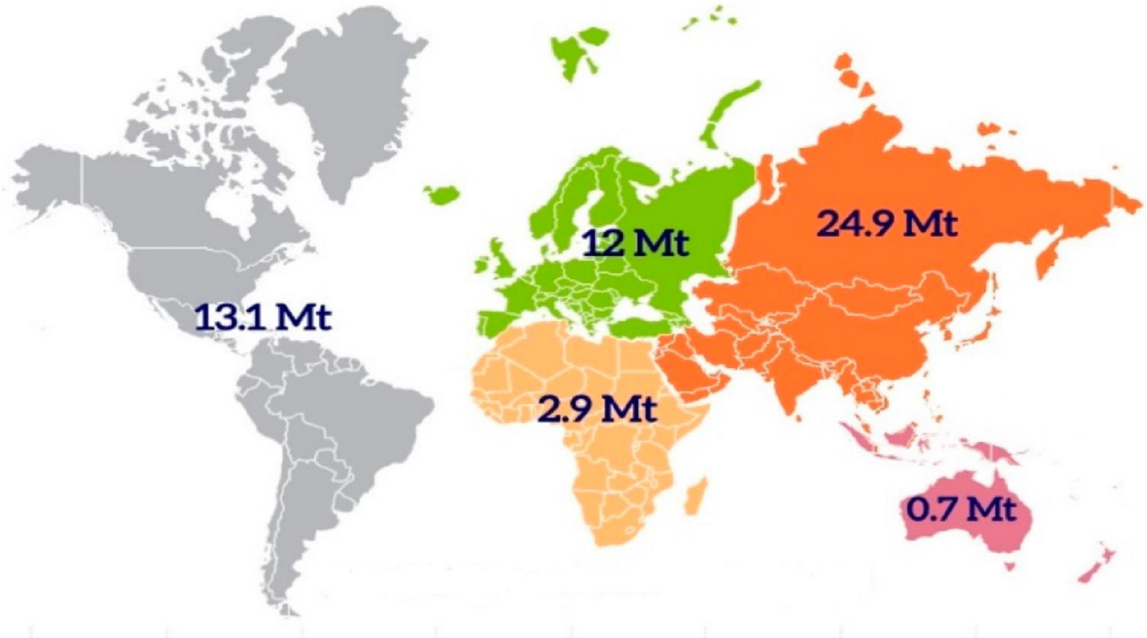

Figure 1. E-Waste producers map (Murthy, & Ramakrishna, 2020)

Recent reports from the Global E-Waste Monitor indicate that the amount of electronic waste may reach 74 Mt by 2030. The main reasons for this dramatic increase of electronic waste are associated with short life cycles designs, technological evolution, high consumption rates and few repair options. As little as 17.4% of WEEE were recycled in 2019. The remaining 82.6 % of unrecycled WEEE are partially composed of precious metals and other critical (i.e., with economic importance and high supply risk) metals. Figure 2 shows the typical composition of E-waste, which contains important parts of metals and plastics. The aggregation of household E-waste is often seen as a source for "urban mining" meaning that it contains multiple elements that, if exploited, can be used as secondary raw materials.

The unrecycled part of electronic waste represents a hazard for human health and the environment. Indeed, EEEs are partially derived from chemical processes and are composed of toxic substances such as lead or mercury. Chemical compounds can leak during recycling or after disposal (United Nations, 2019) and end up in the air and water. Thus, representing a threat to human health and to the environment.

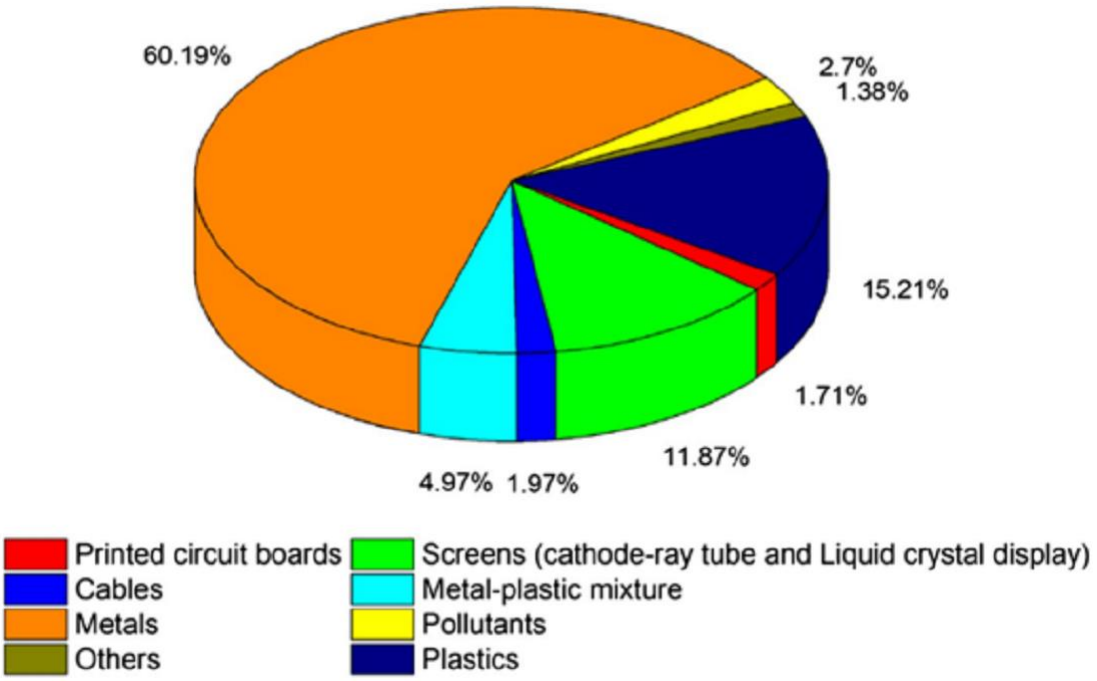

Figure 2 - Typical composition of E-waste (Shahabuddin et al, 2023)

E-waste generation is closely related to the limited lifetime that consumers give to their electrical devices. Due to different reasons, the amount of time that consumers keep their EEEs is less than they intend to. Figure 3 gives the lifetimes of some EEEs, namely smartphones, televisions, washing machines and vacuum cleaners. In this Figure, three types of lifetimes are compared (European Environment Agency, 2020). The actual lifetime represents the interval between the time of sale and the time at which the item is discarded or replaced. The designed lifetime is the lifetime intended by the manufacturer resulting from the design and the after-sale service. The desired lifetime indicates the amount of time that consumers want the device to last. One can see that the desired lifetime usually exceeds the designed lifetime except for televisions. Due to technological obsolescence, consumption habits, lack of repair options and other various reasons, the actual lifetimes of these four EEEs are smaller than the designed or desired lifetime. This means that functioning or repairable EEEs such as smartphones or TV monitors are often discarded.

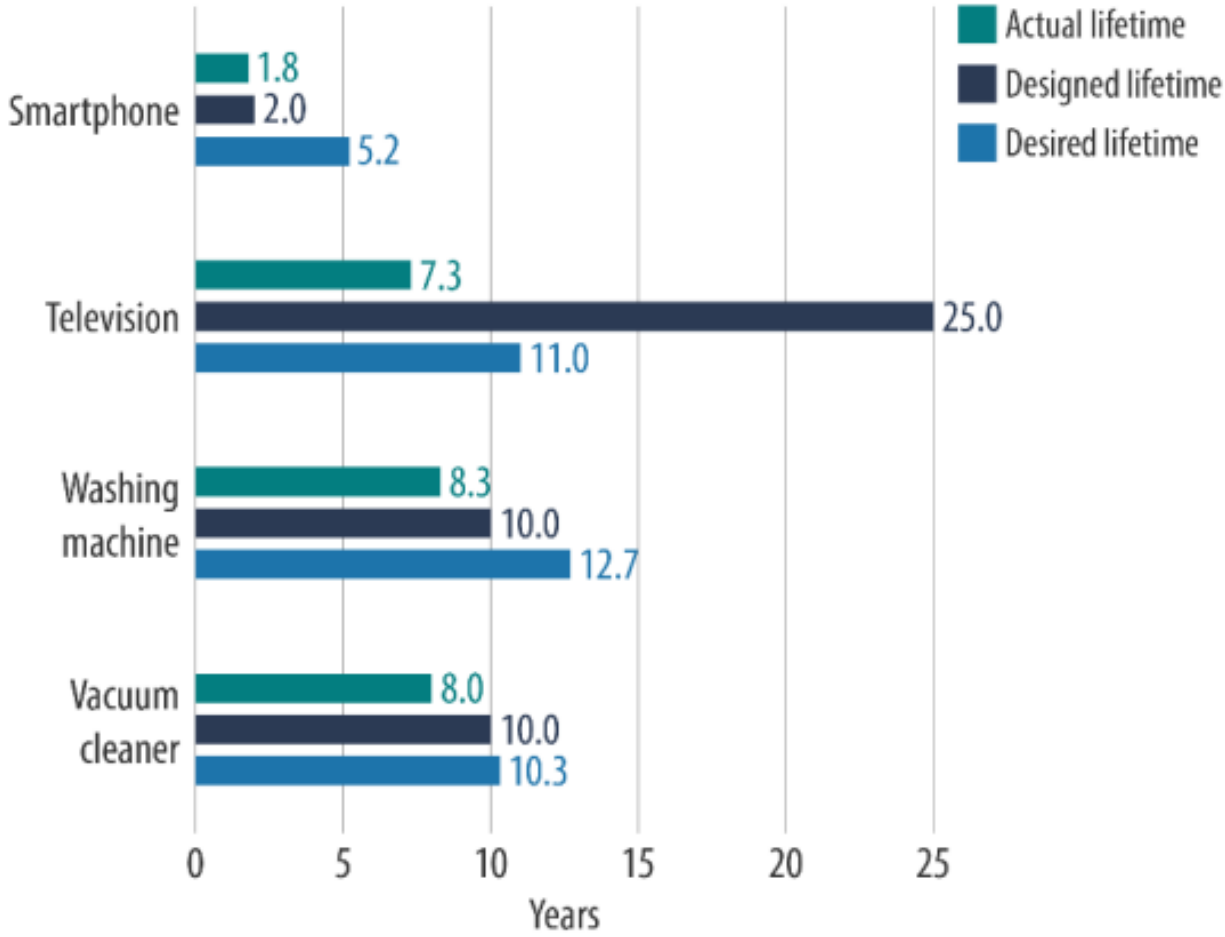

Figure 3- Lifetimes of some EEEs (European Environment Agency, 2020).

1.2 Promoting Repair

Repair is a pillar of circular economy since it allows increasing the devices life span and preventing waste. However, household repair tendencies have decreased over the past decades (Cooper et al, 2018). This trend has been mainly associated with the increased habit of throwing instead of fixing. Besides, people face different barriers towards repair (Svensson-Hoglund, et al, 2022). Some of these barriers are listed below:

- **Design**

Many details preventing repair arise from the design step, which may be associated with business strategies. For example, there is a multiplication of fastener types on certain devices, which makes the reparation harder because it requires access to multiple tools. For example,

some manufacturers may intentionally use different types of screws leading to the need of different specific screwdrivers.

Aside from that, the designer may choose to connect different components using glue. For example, some manufacturers use glue to fasten smartphone screens. The use of glue obliges the repairer to heat the device and thus increases the risk of damaging other parts such as nearby circuitry or cameras with each repair. The intended lack of compatibility or modularity with respect to devices of the same type is also a barrier against repair.

- **Law and warranty**

Manufacturers may deny consumers the right to repair. In many cases, the consumer is given a new device even if she or he prefers to have the old one repaired. Consumers will also often refrain from repairing devices themselves in fear of cancelling warranty agreements.

- **Reparation cost and taxes**

The cost of the reparation is one of the most important barrier. Consumers who have to choose between buying a new device and paying for a reparation that cost nearly as much or more than the device they want to repair will often tend to the former. Taxes for reparation and refurbished spare parts play a major role in the total cost.

- **Repair logistics**

The repair success depends on many factors. One of them is the availability and delay for spare parts. Large delays or lack of availability will impede the effective reparation. The need for specific training, which would oblige repairers to follow long, costly and specific formations, will also prevent repair.

In order to address these barriers and to promote circular economy, different governmental actions and projects from associations and universities are taking place. Among these actions lies the European WEEE directive dedicated to the prevention of E-waste growth. The first WEEE directive, which concerned conditions for electronic devices to come to market, has been released in 2003 (European Parliament and Council, 2003) and focused on the collection, treatment, recovery and environmentally friendly disposal of WEEE. The directive has been

adapted since then (European Parliament and Council, 2012) and contains new measures to protect the environment and human health.

Besides, the 'right to repair' has been discussed in a certain number of documents from the European commission. Notably in the European Green Deal (Fetting, 2020), the new consumer agenda and the new circular economy action plan. The right to repair aims to provide consumers with the ability to repair during the legal guarantee and after it expires. The right to repair also intends for consumers to be able to repair themselves with access to spare parts and documentation. For the time being, the European law does not require manufacturers to provide these elements to consumers. Manufacturers only have to provide professional repairers with spare parts and documentation for specific categories of products.

At the Belgian level, project Sharepair (https://www.sharepair.org/), for example, intends to scale up repair by developing new business models using financial and cost simulations. The project also relies on the development of digital tools, which will inform citizens about repair options and bring them close to Repair Cafés. The project entails the development of city repair toolkit and educational packets to be sent to schools.

Repair constitutes a viable option to strive against the E-waste growth and is a pillar of circular economy. However, considering repair as the only option is not conceivable for the time being. The following Fermi computation give insights regarding this statement.

Let us assume that a common repairer is able to successfully repair or repurpose any EEE thrown away in Belgium. One may ask, "How many repairers do we need to repair or repurpose every device thrown away by the Belgian population?" In order to answer this question, let us make the following estimations:

- In 2016, Recupel stated that the Belgian population generates an average of 22.4 kg of E-waste per person (Recupel, 2016).

- Let us assume that these 22.4 kg, which include large household appliances and small electronic devices, are composed of 10 devices on average. It means that, considering

the Belgian population, $10 \times 11.5 \times 10^6$ devices need to be repaired or repurposed each year.

- Let us now assume that a repairer can repair 10 objects per week on average and works 48 weeks per year. It means that a repairer can repair around 480 objects per year.

- From here we can infer that Belgium requires around 240 000 repairers to balance the yearly E-waste generation.

The number of 10 objects repaired on average has been chosen to approximately reflect the numbers of reparation indicated by the repairers interviewed in the study presented in Section 4 (see Table 3).

The number of repairers resulting from these estimations appears utopic given that it means that 1 person out of 50 needs to be an accomplished full-time repairer. According to (Wallonie Environnement SPW, 2021), the repair community had between 1500 and 1900 full-time equivalents in Wallonia in 2018, which is two orders of magnitude below the required number.

Although repair must be considered to strive against E-waste growth, it cannot be the only option. Indeed, circular economy proposes a systemic approach that includes but is not restricted to repair options.

Let us conclude this section by reminding that, at some point, devices become obsolete to the point that repair is not the best option anymore. For example, this can be due to technological obsolescence. In this case, more recent versions of the device with a lower ecological impact are available. Besides, at some point, the device becomes only short term repairable. For instance, a car that goes beyond 300 000 km is seldom repaired.

1.3 Circular economy through 7R's

Circular economy (Camacho-Otero, et al, 2018; Stahel, 2016) proposes a systemic approach to an economic development with sustainability objectives. One of its main ideas is about turning end of life goods into new resources and thus initiate decoupling between value creation and waste generation.

In this framework, one of the main priorities inside a circular economy is maximizing products life cycles and giving end of life objects new cycles as opposed to traditional linear economy. In this model, loops of industrial systems are closed such that obsolete, broken and end of service devices are refreshed or repurposed as shown in Figure 4.

Figure 4 – Life cycles of circular economy. Source: https://bk-bags.com/what-is-circular-economy/

Circular economy is sometimes associated with a 7R designation corresponding to the following seven actions:

- **Redesign**

  New designs must ease reparation, repurpose or upgrade. This means excluding programmed obsolescence and irremediable failures. For example, the authors of (Rodríguez, & Favi, 2022) propose eco-design guidelines to design sustainable future cooking appliances.

- **Reuse**

  Reuse objects for the same purpose using life extension strategies (Bovea, Ibáñez-Forés, Pérez-Belis, & Quemades-Beltrán, 2016). Important amounts of EEEs are discarded after minimal use. Studies have shown that between 20 and 30 % of WEEE are composed of reusable devices (Agumutu, Cooper, & Herat, 2012).

- **Recycling**

  Recycle objects by disassembling the different components and extract resources, which can act as secondary raw materials. Recycling of EEEs has become an important challenge due to the presence of hazardous substances, as mentioned before. The lack of infrastructure and technological obsolescence often prevent efficient recycling (Shahabuddin, et al, 2023).

- **Reconvert**

  Convert non-recyclable components into energy through combustion for example. As shown in Figure 2, E-waste contains an important part of plastics. Thus, energy recovery from E-waste is possible through incineration of polymers (Ma, et al, 2016).

- **Refurbish or Renew**

  Gather components from old devices and give them a new purpose. For example, the organization 'Oud Now' gathers old cabinets to make new cabinet designs (https://www.oudnow.nl/).

- **Reduce**

  Reduce energy and materials consumption by adopting a more environmentally friendly and more sober lifestyle.

- **Repair**

  Extend the life of objects by choosing the repair option instead of buying new objects.

Depending on the situation, one has to choose which of those actions is the most appropriate. Closing loops thanks to the 7R options will allow minimizing waste and significantly reducing greenhouse gas emissions.

The close interdependencies between circular economy and sustainable development goals (Assembly, 2015) (shown in Figure 5) have been studied in (Schroeder, Anggraeni, & Weber, 2019). In this paper, the authors show that circular economy has the strongest links with SDG 6 (clean water and sanitation), SDG 7 (affordable and clean energy), SDG 8 (decent work and economic growth), SDG 12 (responsible consumption and production) and SDG 15 (life on land).

Figure 5- Sustainable Developments Goals (SDGs)

Chapter 2. The French repairability index

This chapter starts by introducing the French Repairability Index (FRI). The details of the index calculation and its criteria for evaluation are given. The Chapter also comprises a literature review, which highlights the pros and cons of the FRI and gives some insights about how the FRI can be a guideline for design. Finally, the FRI is compared with other repair metrics such as the iFixit index.

2.1 Introduction of the index in France

The French repairability index (FRI) results from the application of article 16-l of law 2020-105 which has been proposed in the context of a campaign prioritizing circular economy and preventing E-waste. The main objective of the FRI is to inform consumers about the possibility of increasing the life span of their objects. Thus, encouraging consumers to steer towards repair and buying repairable devices. This action also strives against planned obsolescence.

According to the Agence de l'Environnement et de la maîtrise de l'Energie (ADEME), only 40 % of damaged EEE were effectively repaired in France in 2020. With the introduction of the index, the French ministry intends to increase the proportion of repaired EEE to 60 %. The FRI is a score out of 10 supported by a color code as depicted in Figure 6.

Figure 6 - French index of repairability.

Since 2021, the FRI evaluation and display are mandatory for five types of objects (smartphones, laptops, front-loading washing machines, TV monitors and electric lawn mowers). The mandatory calculation and display of the index have been extended to another four categories of objects on November 4, 2022. The additional categories are top-loading washing machine, dishwashers, three types of vacuum cleaners (fed by electric cables, with battery and robot) and high-pressure cleaners. Sellers of electronic equipment must provide the consumer with a repairability index free of charge. Sellers also need to be able to communicate the modalities of the evaluation of the index at the time of sale.

The display modalities are defined by decree. These mention that sellers are required to display the index next to the price at the time of sale. Sellers also need to provide consumers with the details of the index calculation if required by the latter.

Regarding online sale, the index must appear on any webpage that leads to the purchase of the product. The details allowing the index calculation need to be reachable from the same purchasing page.

The French federation intends to convert the FRI to a sustainability index by 2026.

2.2 Index calculation

The French Ministry for ecological transition provides an evaluation grid (see Table 1), which enables the calculation of the index for a given object. The index is obtained by evaluating five main criteria: the documentation, the ease of dismantling, the availability of spare parts, the spare parts price and a specific criterion, which depends on the category of the object. For example, in the case of laptops, smartphones and TV monitors, the specific criterion includes the information and assistance regarding software updates. Concerning these objects, the specific criterion also comprises the possibility of software rebooting.

Each of the top five criteria is subdivided into sub criteria. While sub criteria have different weights, the main five criteria have the same weight relative to the final score. This means that one obtains the index of a given object by calculating the arithmetic mean of the five main criteria. This feature affects the credibility of the index as will be discussed in Section 2.3.

The FRI grid of the Iphone 14 Pro Max is given in Fig. 7 as an example. In this case, the specific criteria correspond to the software updates information, the free remote assistance and the software rebooting availability.

A total score of 7/10 is given. This score may give the impression that this device is relatively easy to repair. However, when looking at the evaluation grid, one observes that the scores corresponding to the duration of availability of list 2 spare parts and delivery delays for list 1 spare parts both show a score of 1.7/10. This means that, while hands-on repair should be relatively easy, the availability and delivery delays might prevent repair due to logistic issues. Considering this extremely low score, it may be possible that the duration of availability of list 2 spare parts corresponds to only a few months. Besides, the low score associated with the delivery delays of list 1 spare parts may indicate that delivery delays may take more than several weeks. The person who desires to repair this phone may face the issue of being unable to acquire spare parts or may have to wait too long for their delivery. Considering the importance of phones in people's lives, this person will certainly not want to wait many weeks for spare parts and will acquire a new phone instead.

Criterion	Sub criterion	Sub criterion score	Sub criterion coefficient	Criterion score	Total score
1. Documentation	1.1 Duration of availability of the technical documentation and relating to advice on use and maintenance	/10	2	/20	
2. Dismantling and access, tools, fasteners	2.1 Ease of parts disassembling	/10	1	/20	
	2.2 Necessary tools	/10	0.5		
	2.3 Characteristics of fasteners between parts	/10	0.5		
3. Availability of spare parts	3.1 Duration of availability of spare parts from list 1	/10	1	/20	/100
	3.2 Duration of availability of spare parts from list 2	/10	0.5		
	3.3 Delivery delay for list 1 spare parts	/10	0.3		
	3.4 Delivery delay for list 2 spare parts	/10	0.2		
4. Spare parts price	4.1 Ratio of list 2 parts prices to price of new equipment	/10	2	/20	
5. Specific criterion	5.1	/10	2	/20	
Score of the index					/10

Table 1 - Evaluation grid for the FRI, provided by the French ministry of ecological transition.

Critère	Sous-critère	Note du sous-critère sur 10	Coefficient du sous critère	Note du critère sur 20	Total des notes des critères sur 100
CRITÈRE 1 : DOCUMENTATION	1.1 Durée de disponibilité de la documentation technique et relative aux conseils d'utilisation et d'entretien	7,7	2	15,4	69,8
CRITÈRE 2 : DÉMONTABILITÉ, ACCÈS, OUTILS, FIXATIONS	2.1 Facilité de démontage des pièces de la liste 2*	5,0	1	10,3	
	2.2 Outils nécessaires (liste 2)	2,5	0,5		
	2.3 Caractéristiques des fixations entre les pièces de la liste 1** et de la liste 2	8,0	0,5		
CRITÈRE 3 : DISPONIBILITÉ DES PIÈCES DÉTACHÉES	3.1 Durée de disponibilité des pièces de la liste 2	10,0	1	14,2	
	3.2 Durée de disponibilité des pièces de la liste 1	1,7	0,5		
	3.3 Délais de livraison des pièces de la liste 2	10,0	0,3		
	3.4 Délais de livraison des pièces de la liste 1	1,7	0,2		
CRITÈRE 4 : PRIX DES PIÈCES DÉTACHÉES	4. Rapport prix des pièces de la liste 2 sur prix de l'équipement neuf	5,0	2	10,0	
CRITÈRE 5 : CRITÈRE SPÉCIFIQUE	5.1 Informations sur la nature des mises à jour	10,0	1	20,0	
	5.2 Assistance à distance sans frais	10,0	0,5		
	5.3 Possibilité de réinitialisation logicielle	10,0	0,5		
Note de l'indice sur 10					**7**

*liste 2 : liste des 3 à 5 pièces détachées au maximum (selon la catégorie d'équipements concernée) dont la casse ou les pannes sont les plus fréquentes ;

**liste 1 : liste de 10 autres pièces détachées au maximum (selon la catégorie d'équipements concernée) dont le bon état est nécessaire au fonctionnement de l'équipement.

Figure 7 - The FRI grid of the Iphone 14 Pro Max (https://support.apple.com)

2.3 Literature review for the FRI

The Halte à l'Obsolescence Programmée (HOP) organization did report the pros and cons of the FRI based on the analysis of a database containing details of about 2000 FRI scores (Halte à l'Obsolescence Programmée, 2022). They confirmed that the FRI is able to inform the consumer about the different repair complexity between different types of objects (the complexity of washing machines is not the same as the one of laptops). HOP also reports that the FRI has motivated manufacturers to increase the amount of available repair documents.

HOP reported that only very few devices have low FRIs (<1.9/10), indicating that the FRI may not be efficient enough to isolate hard-to-repair devices. HOP also reports that, despite their mandatory display, indexes may not be found for many devices belonging to some classes of objects such as laptops.

Besides, HOP shared some concerns regarding the transparency of the index and vouch for the development of a public site regrouping the calculation details of the index for every device and not only a grid with the sub criteria scores. HOP believes that this will facilitate the control by the market and consumers apprehension.

HOP found that the index is usually too generous and that the scoring system should be reviewed. This conclusion also appears in (Roisin, Toussaint, Swaen, & Raskin, 2023), where the authors pointed out that the global score is the result of an arithmetic addition of equally weighted sub criteria. This scoring system allows manufacturers to exhibit a good reparability index despite a very low score in one of the sub criteria. For example, let us suppose that the availability or price of spare parts is such that criteria 3 or 4 is null. In this case, the index can still reach a score higher than 7 by maximizing the other criteria. This can bring the consumer to think that the device can be repaired whereas the reparation is difficult or even virtually impossible due to the lack of spare parts or if the spare parts price is too high. To mitigate this limitation, the authors of (Roisin, Toussaint, Swaen, & Raskin, 2023) mentioned that other methods could be used to calculate the global score, such as using the geometrical mean of the sub criteria scores.

The work presented in (Fonteijne, 2021) focused on the reparability evaluation for vacuum cleaners, which need to be sold with their FRIs in France since November 2022. The author of (Fonteijne, 2021) proposes tools (such as disassembly maps) and guidelines on how to design for FRI. This process ensures high and reliable FRI scores for vacuum cleaners. The main features of this process include keeping the amount of disassembly steps low to obtain priority parts. This is done by placing priority parts close to the surface, ensuring that priority parts are separable from each other and limiting the number of tool changes.

2.4 Comparison of the FRI with other metrics

Over the last decades, different classes of tools able to give insights regarding products repairability emerged. For example, some tools were used to assess the ease of disassembly based on time measurements (Desai, & Mital, 2003; Kroll, & Hanft, 1998). These methods usually measure the time of standard disassembly activities (such as unscrewing, fixturing or peeling) and do not measure the total disassembly time, which significantly depends on the experience of the repairer. These methods can also serve when it comes to evaluate products recycling and maintenance.

Metrics for repairability first appeared in the 90s. Since then, many different metrics based on different criteria emerged. Table 2 shows five well-established metrics which can be used to assess repair (Ruiz-Pastor, & Mesa, 2023). One can see that some indexes are based on more than 10 criteria and are therefore significantly more elaborated than the FRI. Besides, it appears that each index has specific criteria for spare parts and disassembly, indicating that these two criteria are essential when evaluating repairability.

The iFixit/Flipsen index (Flipsen, Bakker, & van Bohemen, 2016), which is a more experienced index than the FRI, is also dedicated to electronic products. The index provided in (Flipsen, Bakker, & van Bohemen, 2016) has been elaborated based on a study where the repair criteria were crowdsourced from a massive open online course. Almost 2000 entries were analysed and structured into 26 criteria for repair. Although the evaluation of the Flipsen index requires deeper studies, it may better reflect the repairability of the object than the FRI. Some criteria such as the cost of repair, the easy access to critical components, the standardization of spare

parts, the ease of identification of the problem or the indication regarding the training needed are very relevant for repair and do not directly appear in the FRI.

It should be pointed out that, contrary to the FRI, the iFixit index must not legally be displayed at the time of sale. Hence the FRI has more visibility and can be more easily used to inform and aware consumers.

It has been noted in (Ruiz-Pastor, & Mesa, 2023) that the indexes listed in Table 2 allow measuring the reparability of devices but do not give indications on reparability weaknesses relevant to redesign processes. The index proposed in (Ruiz-Pastor, & Mesa, 2023), namely the Product Reparability Index (PRI), provides information towards the most critical components and potential redesign interventions in the spirit of giving devices a maximum of life cycles through repair and redesign.

Table 2 - Metrics for repairability assessment (Ruiz-Pastor, & Mesa, 2023).

Metric or indicator	**Focused on**	**Criteria and Scoring System**
French Repairability Index	Electronic products (smartphones, laptops, televisions, washing machines, lawnmowers)	**Five criteria**: Documentation, disassembly (accessibility, tool, fasteners), availability of spare parts, price of spare parts, criterion specific to the category for equipment concerned. 0-20 points range and normalized to 0-10.
EN 45554:2020 (European committee for Standardization, 2020)	Energy-related products	**11 Rating criteria**: Disassembly depth, fasteners, tools, working environment, skill level, diagnostic support and interface, availability of spare parts, types and availability of information, return models, data transfer and deletion, password and factory reset for reuse. Classes A-F, aggregation: numeric values for each class.
JRC Analysis (Spiliotopoulos et al., 2021)	Generic products	**Six parameters**: Disassembly depth, fasteners (type), tools (type), spare parts (target group), software updates (duration), repair information. 1-5 score per criterion and weighted importance.
BENELUX Repairability criteria (Bracquené et al., 2018)	Energy-related products	**Three main criteria types** (Information provision, product design, service) across five repair steps that include product identification, failure diagnostic, disassembly & reassembly, spare part replacement, and restoring to working condition. Normalized to 0-100%.
iFixit/Flipsen (Flipsen, Bakker, & van Bohemen, 2016)	Electronic portable products	**26 criteria** that include: Repair manual available, no special tools needed, easy access to critical components, cost of repair/ spare parts/tools, standardized spare parts, risk of injuries, no excessive amount of adhesive, ease of identification of the problem, no comprising other components, identification of components, availability of tools, no special training needed, number of tools, upgradeability, self-explanatory repair processes, recyclable components, other. Normalized to 0-10.

Chapter 3. Repairers' feedback on the FRI

The goal of this research is to question Belgium's repair community and investigate the potential usefulness and the current credibility of the FRI. The qualitative analysis realized in this work aims at providing some answer to the following questions:

- **Do Belgian repairers know and use the FRI?**

The FRI evaluation and display are mandatory in France. It is unclear whether Belgian repairers currently know or use the FRI. The first goal of this work is to determine if the FRI is used in Belgium and, if so, how is it used?

- **What is the repairers' opinion about the FRI criteria?**

The primary goal of the FRI is to promote consumers' awareness regarding repairability of the devices they buy. The FRI should motivate people to move towards products with high FRI such that they will be more inclined to repair these products in the event of breakage. However, one may wonder how the FRI is perceived by the repair community. Do they think that the FRI represents a reliable asset towards repair? Do they think that the FRI will inspire consumers to visit repairers?

- **Can repairers include the FRI in the decision to repair or not?**

Repair is a time-consuming activity which can also be expensive. In order to efficiently repair many devices, the repairer has to decide whether devices are worth repairing or not. This decision will involve availability of spare parts, delivery delays and availability of required tools. The different costs associated with repair will also be taken into account. The repair costs include labor hours, taxes and spare parts costs. The repairer will also need to assess whether he has the required expertise or not.

The FRI, mainly through its evaluation grid (Table 1), gives insights regarding these criteria. Thus, one may wonder if the FRI scores or grids can be used to accelerate the time required by the repairer to assess the repair complexity.

This Chapter is structured as follows. The first Section describes the profiles of the speakers. The data is analyzed in the second Section. Finally, Section 3.3 summarizes the main results of this work.

3.1 Data collection

The repair community is broad and goes from voluntary individuals to large repair companies. Actors in this community are most of the time willing to share repair technics and information. For example, one can find many Repair Cafés where people can visit and consult experienced voluntaries to fix broken devices. Another example is iFixit (Getto & Labriola, 2016): a worldwide community based on shared experience where one can create and edit free repair tutorials or share technical experience.

This research is based on a qualitative study with semi-structured interviews allowing speakers to bring new information. The data sample proposed here is not statistically representative, however, the repair community being composed of multiple types of repairers, the study targets different profiles to diversify feedbacks on the FRI. The informants occupy different positions in the repair community and therefore experience a different approach concerning repairability. While repair is a professional occupation for some of the informants, it is a voluntary hobby for others.

The profile and details of the interviews are given in Table 3. The data samples contain four different types of repairers: voluntary repairers from Repair Cafés, professional repairers, a Fabrication Laboratory manager and research technicians working at the University of Louvain. Descriptions of the four profiles are given below.

- **Repair Café repairers**

Repair Cafés are local initiatives allowing people to bring defective objects for repair. These are also places of knowledge sharing where people learn to repair together. Repair Cafés are driven by voluntary actors, who often possess a strong technical repair background. Repair Cafés also ensure links with professional repairers. If repair requires spare parts or if professional help is required, people are redirected towards professional repairers. In 2021, 143 Repair Cafés were registered in Wallonia (Wallonie Environnement SPW, 2022).

This study contains interviews with two repairers from two different Repair Cafés, both located in Louvain-la-Neuve. The first Repair Café takes place in the Maison du Développement Durable (MDD) on a weekly basis. The person interviewed from this organization is a retired mechanical engineer. This Repair Café tries to repair any kind of device, including those with electrical and mechanical designs.

The second Repair Café corresponds to the student organization entitled 'the Electrokot'. The Repair Cafés organized by the Electrokot take place on a weekly basis. The interviewed speaker from this organization is a computer science student. While the primary focus of the Electrokot was to repair any kind of EEEs brought by people, they recently narrowed the range of devices they try to repair. Based on experience, they decided to omit the repair of coffee machines, home appliances and some brand of smartphones. These reparations were significantly time-consuming and had a low success rate. Today they mainly focus on smartphones and laptops. These restrictions on devices selection enabled reaching a better repair success rate. The Electrokot manages to effectively repair between 6 and 8 devices per week.

- **Professional repairers**

Professional repairers offer different services. Repair business can be developed on spare parts providing, consulting or effective repair. While repair can be free in Repair Cafés, repair has a cost in professional institutions. However, professional repairers are more inclined to provide spare parts and greater expertise. The total cost of repair includes taxes, labor cost and spare parts cost.

In this study, the first interviewed professional repairer is an employee from Idoctor (http://www.i-doctor.be/). Idoctor mainly focuses on electrical devices such as smartphones, tablet computers and laptops. They offer other services besides repair. They propose devices enhancement (by providing more performant parts for example) and they offer to buy out people functional and no longer used smartphones and laptops. The Idoctor shop of Louvain-la-Neuve manages to repair about 50 devices per week.

The second professional repairer works at Electro Zschau. This shop is mainly dedicated to the sale and repair of house appliances such as washing machines, fridges and dishwashers. Electro Zschau maintains a close relation with their clients and one of their goals is to offer clients durable and reliable house appliances. To this end, they actually use the FRI to advise clients on future repair options. Electro Zschau repairs between 6 and 10 devices per week. Both Idoctor and Electro Zschau gave their authorizations to summarize the content of the interviews in this manuscript.

- **Fabrication Laboratory (FabLab)**

FabLabs are local, small laboratories gathering knowledge, tools, and machinery. These are places where people can learn and realize personal projects. These are not repair laboratories per se, however they contain all the experience and tools needed to cover a broad range of common repairs that people require. FabLabs can be the initiator of local business activities. Studies relying on Fablabs as the core of an alternative electronics economy are taking place (Lebrun, Raskin, & Toussaint, 2022).

Design has proven to be a strong barrier to repair as explained in Section 1.2. Products designed in FabLabs would be composed of local materials and would be given a maximum of life cycles through repair, recycling, and refurbishment. In addition, Fablabs machines are defined within standards, meaning that products designed in each Fablab can be repaired or used in other Fablabs. This study contains the inputs of the Louvain-la-Neuve Makilab manager.

People do not often go to Makilab for repair even if Makilabs contain all the required tools and expertise required for many simple repairs. They usually go there to realize personal projects. The Makilab in Louvain-la-Neuve repairs about 10 devices per year.

- **Research technicians**

While the FRI targets massively sold devices such as smartphones and laptops, one should not forget that EEEs result from technological research. Modern devices are derived from the standards of modern technology. Most of the time, designs made for previous generations cannot be used for new ones. For example, devices dedicated to the third and fourth

telecommunications generations will not be used for 5G and 6G. This is due to the fact that previous designs show lower performance, are less power efficient and are dedicated to other frequency bands. This trend is reflected in today's markets. Indeed, old technology devices are generally not used to build new technology devices.

In this framework, research technicians have a clear view on the evolution of hardware systems developed in research and which eventually end up on the market. They are used to repair electronic devices such as printed circuit boards or antenna systems, which can be found in smartphones and laptops. In this context, three research technicians from the UCLouvain have been interviewed.

Table 3- Data Samples

Organization type	Organization name	Function	Interview duration	Date	Number of reparations	Interview number
Repair Café	Maison du développement durable	Retired engineer	30 min	08/03/2023	-	1
Repair Café	Electrokot	Student	40 min	22/03/2023	6-8 per week	2
Professional repairer	IDoctor	Professional Repairer	30 min	12/04/2023	~50 per week	3
Professional electro seller and repairer	Elecro Zschau	Professional Repairer	25 min	14/04/2023	6-10 per week	4
Fabrication Laboratory (FabLab)	Makilab	Fablab manager	50 min	30/03/2023	10 per year	5
University	UCLouvain	Research technician	25 min	07/03/2023	-	6
University	UCLouvain	Research technician	60 min	17/03/2023	-	7
University	UCLouvain	Research technician	40 min	27/03/2023	-	8

3.2 Results analysis

The data collected from the interviews provide some answers to the questions raised at the beginning of this Chapter.

3.2.1 Knowledge of the FRI and repairers' global opinion

The study shows that most of the questioned repairers have a basic knowledge of the FRI. Most of them know of its existence but do not know on which criteria the FRI is evaluated. However, all the interviewees were enthusiastic regarding the introduction of a mandatory reparability index. All of them confirmed that it represents a step towards encouraging reparability. Some of the interviewees think that, if consumers have to decide between devices with sensible price differences, they will tend to choose the device showing the highest reparability score. One informant mentioned the example of Fairphone (Akemu, Whiteman & Kennedy, 2016). Fairphone offers sustainable smartphones with a special attention for reparability. The success of Fairphone highlights the market demand for repairability.

Some of the informants shared their concern regarding the limits and potential lack of credibility of the FRI. The fact that most of the scores are high and the lack of manufacturers' transparency might hinder the impact of the FRI.

The assessment of repairability is often a question of experience. After some time, repairers know which brand or designs will lead to tedious and time-consuming repair. However, most of them mentioned that a well calculated FRI might help to decide whether repair is worth or not.

Informant 1 expressed that the FRI will especially be useful for the consumer and not for the repairer. The informant further explained that, in many cases, the repairer does not reach for spare parts and seek alternatives. While this may be the case for some devices, many reparations actually require the exact spare part. For example, smartphones cameras are not interchangeable and repair usually requires the exact same model.

Besides, several informants think that, provided that the FRI becomes a credible index, a minimum score should be required to bring a product on the market. They think that this restriction would inspire manufacturers to produce devices meant to be repaired and that would

not be rapidly disposed of. Another informant mentioned that more severe taxes should be raised for devices with low repairability scores.

3.2.2 Current use of the FRI

Except for informant 4 (Electro Zschau), none of the interviewees currently use the FRI.
The informant from Electro Zschau mentioned that at least 70% of their clients seek to buy sustainable and reparable devices. Accordingly, employees from Electro Zschau consult the FRI grids to guide clients towards repairable devices. However, informant 4 revealed that they do not use the FRI global score, which for them does not yet indicate true reparability. They consult the detailed grids associated with the FRI (see Table 2).

While Electro Zschau employees do use the FRI to guide clients towards repairable devices, they do not yet use the FRI to make repair decisions. They maintain a database of products that they consider for repair. The database is built on experience. They already know how to repair the registered products. Nevertheless, they revealed that they might consult the FRI to decide which future products will be added to their repair database.

It seems that repairers usually make decisions to repair based on experience or ask the clients to give them time to do some research in order to assess the time and cost of repair. Informant 2 mentioned that the Electrokot Repair Café maintains a database allowing to share repair experience inside the organization and to assess which products are more prone to repair. Based on this experience they select the devices they try to repair. As it happens, the Electrokot does not repair home appliances anymore and mainly focuses on smaller electronic devices such as smartphones, tablet computers and laptops. This decision enabled a higher repair success rate.

3.2.3 Repairers' opinions on selected criteria

The five criteria selected by the French ministry of ecological transition are the availability of documentation, the ease of disassembly, the availability of spare parts, the spare parts price and a specific criterion depending on the category of the device.

All the informants think that the criteria are properly selected but most of them think that other criteria are required to truly reflect repairability.

However, informant 2 thinks that, at this point, the main efforts must be oriented towards the consumer. Hence, guiding the latter towards the brands offering the most repairable devices.

Informant 2 also added that most of the persons coming to the Electrokot for repair are either students or pensioners. The informant indicated from there that most of the people consulting for repair are people with less money such as students or people having more time such as pensioners. Active people having money and a busy schedule might be less inclined to take the time to repair their defective devices.

3.2.4 How the FRI could be improved

The repairers interviewed in this study addressed the limits of the FRI and shared some potential missing criteria for the evaluation of this index. Most of the informants think that other criteria should be accounted for in the evaluation of a device repairability score. The description of these additional criteria is given below.

- **Availability of repair guides**

While the FRI already gives a score for the availability of documentation, some of the informants mentioned that the referred documentation does not always provide a tangible help towards repair. Sometimes, the documentation appears less as a repair guide than a user guide, which does not propose exploded views or hints towards which part might be broken.
Informant 8 thinks that real guides for repair with a root-cause analysis should be made available. The root-cause analysis would allow to rapidly identify and replace the defective parts. Informant 8 added that the repair guides should also contain a table associating errors to the degree of expertise needed to repair the device. This table would inform if repair can be done by the consumer of if it requires the expertise of a Repair Café or a professional repairer.

The informants are aware of the intellectual property issues associated with such repair guides. However, they think that, after some time, the repair guides should be made available. Determining the time between when a product is put on the market and when the associated repair guide is made available remains an open question.

- **Modularity or standardization criterion**

Standardization of spare parts allows faster repair. Repairers and even consumers usually dispose of a stock of standardized parts and if not, these parts can be obtained faster than specific parts. Thus, repair is made easier when defective parts correspond to standard parts.

European Commission made a step towards this direction by proposing that all electronic devices such as smartphones, headphones and tablets use a USB type-C charger (Commission, 2022). This rule is planned to be applied in 2024 and does only concern new products.

Informant 5 agrees that a standardization criterion will be helpful towards repair. This is particularly the case if the criterion reflects the modularity of spare parts in the context of Fablabs. In this case, the index would help select machines for which spare parts can be made available faster or which can be recycled in Fablabs.

- **Single or multi pack spare parts**

As mentioned by informant 4, there are a lot of situations where the repairer can isolate the defective part but where purchasing and replacing this unique part is not possible. Informant 4 gave the example of refrigerator sensors. In lots of cases, when a refrigerator temperature sensor is defective, the sensor cannot be single-purchased and must be bought with other parts. In this case, the cost rapidly increases and repair becomes too costly. Thus, the consumer usually buys a new refrigerator. This happens often with washing machine bearings as well. Accordingly, a good repairability index should indicate if spare parts can be obtained in single packs.

- **Lifetime criterion**

Several informants mentioned the need for an index precising the lifetime of a given product. This information will help the repairer decided if the device is worth repairing or not. Besides, the lifetime information will help consumers to choose durable devices and will motivate them to repair if the device is broken long before the end of its lifetime. One may think that this criterion will be part of the sustainability index supposed to replace the FRI by 2026.

- **Repair cost**

The FRI gives some insights about the global repairability of a given product. While it comprises the spare parts cost, the total repair cost cannot be clearly deduced from the index. This is mainly due to the lack of information regarding the labour cost and the time required for typical repair. Some of the informants think that the index should also indicate the order of magnitude of the typical repair budget associated with a given product.

Informant 4 also shared that some brands lock customer support such that their products can only be repaired by their own technicians. In this situation, repair is usually very costly.

3.2.5 Repairer's opinion on who evaluates the FRI

Manufacturers currently evaluate and fill the FRI grids for their own products. All the informants raised some concern regarding this approach. They think that manufacturers tend to overrate their FRIs and that some regulation should be introduced. Some informants think that an association of independent repairers would be the best option to control the credibility of the FRI. This could be done through the sharing of a database gathering experiences from repairers and in which one would find an evaluation of repairability for different products.

3.3 Conclusion of the analysis

Throughout this study the inputs from repairers belonging to different repair communities have been gathered. From here, it is clear that these repairers do not yet use the FRI except for informant 4 who uses it mostly to inform customers. The other informants explained that they could use the FRI to accelerate repair decisions in the future provided that the index acquires more credibility. The study also showed that repairers agree with the selection of the FRI criteria. However, they mentioned that the FRI should include other criteria to reflect true repairability. They gave some examples such as a standardization criterion, the availability of true repair guides or a lifetime criterion.

Conclusion

E-waste results from our regular disposal of electric and electronic equipment. Our traditional linear economy, based on three actions: buy, use then throw away, has led to dramatic increase of discarded electronic equipment. Today, the aggregation of millions of tons of E-waste is recognized as a concerning matter regarding environment and human health. Indeed, electronic products contain important amounts of hazardous substances, which, if not disposed of carefully, can be harmful to ecosystems.

In order to slow down the growth of E-waste, different actions have been taken at the European and national levels. Those actions usually rest on the pillars of circular economy, which, as opposed to linear economy, aims at giving a maximum of life cycles to commercial products. For example, recycling, refurbishing, renewing or repairing products can lead to new life cycles.

Repair is one of the pillar of circular economy. However, the repair option is facing different barriers including repair cost, technological obsolescence, unavailability of spare parts or lack of information regarding products repairability. In 2020 in France, only 40 % of defective electronic and electric equipment are repaired.

In the face of this situation, the French government introduced the French repairability index in 2021. The index takes the form of a score out of ten resulting from the evaluation of five criteria: the documentation, the ease of dismantling, the availability of spare parts, the spare parts cost and a criterion related to the product specific category. The index aims at steering consumers towards products showing better repairability. The index evaluation and display is mandatory in France for nine categories of products which, for instance, include smartphones and laptops.

The repair community is one of the most important stakeholder regarding the potential success of the repairability index. In this context, some important questions arise: what is the opinion of repairers concerning the index? Can they use the index to pre-evaluate the time and logistic required for repair and, from there, decide whether products are worth repairing or not?

In this work, different actors of the Belgian repair community have been interviewed in order to bring answers to those questions. The repair community being composed of different profiles,

this work includes inputs from informants belonging to different communities such as Repair Cafés, professional repairers, fabrication laboratories (FabLabs) and research technicians.

The study lead to the conclusion that repairers globally appreciate the French repairability index. The study also highlighs the fact that some professional repairers already use the index to guide consumers towards repairable products. However, the informants mentioned that the current version of the index is limited and that, while the evaluation grids containing the subcriteria appears useful, the global score does not truly reflects repairability. They think that the index should entail other scoring criteria related for example to the spare parts standardization or modularity. The products lifetime and the true repair cost, which includes the labor cost, should also be reflected by the index.

The repairers' feedback, through the addition of these criteria to the FRI, could strengthen the credibility and usefulness of the index and facilitate the transition from a repairability index to a durability index as planned by the French government by 2026.

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Résumé :

Chaque année, d'importantes quantités de Déchets provenant d'Equipements Electroniques et Electriques (DEEE) sont générées. Les rapports du Global E-waste monitor indiquent que 53.6 millions de tonnes de DEEE ont été générées en 2019 et que ce chiffre pourrait atteindre 74 millions de tonnes d'ici à 2030. Les DEEE sont partiellement composés de substances dangereuses qui, si elles ne sont pas traitées correctement, peuvent être libérées dans l'air et les eaux, constituant ainsi une menace pour les humains et les écosystèmes. En réponse à cette alarmante situation, les gouvernements prennent des directives. Par exemple, le gouvernement français a mis en place un indice de réparabilité qui doit obligatoirement figurer en magasin. Avec cet indice, le gouvernement français entend favoriser la réparation et encourager les consommateurs à acheter des produits conçus pour être réparés. La communauté des réparateurs joue un rôle essentiel dans le potentiel succès de cet indice. Par conséquent, il est légitime de se demander comment l'indice va affecter les réparateurs et comment celui-ci va pouvoir influencer les réparations effectuées par ces derniers. Cette étude entend clarifier ces éléments grâce aux contributions de divers réparateurs collectées à travers des entretiens semi-directifs. L'étude reporte notamment l'enthousiasme des réparateurs quant à la mise en place de l'indice. Néanmoins, certains ajustements sont nécessaires pour que l'indice reflète précisément la réparabilité des produits.

Abstract:

Each year tremendous amounts of waste from electronic and electric equipment, also referred as E-waste, are generated. The Global E-waste monitor reported the generation of 53.6 million tons of worldwide E-waste in 2019. Based on the current trend, the total weight of E-waste could reach 74 million tons by 2030. E-waste being partly composed of hazardous substances, its inadequate disposal represents a threat to people and ecosystems. In response to this alarming situation, governments take actions to encourage circular economy in order to decouple value production from waste generation. In this context, the French government came up with the French repairability index with the aim of guiding consumers towards products designed for repair and thus increasing repair tendencies. The contribution of the repair community is essential for the success of the French repairability index. This raises the question of how the index will affect the repair community and to what extent the index can be a guiding tool for repair. This study aims at clarifying these points with contributions from repairers from Repair Cafés, Fabrication Laboratories, Universities and professional organizations, collected through semi-structured interviews. The study notably reports the enthusiasm of the repair community regarding the establishment of the index. However, some adjustments may be required for the index to better reflect true repairability.

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