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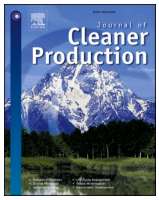

From "right to repair" to "willingness to repair": Exploring consumer's perspective to product lifecycle extension

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ABSTRACT

This paper explores consumer barriers to repair to understand the factors preventing users from extending products' lifecycles. Environment policies to promote Right to Repair stimulate manufacturers to perform proper product lifecycle management. However, the success of such initiatives depends to a significant degree on the consumers' willingness to collaborate. In the case of a product failure, consumers decide what to do with the product. Through a systematic literature review and empirical analysis, we identified 26 barriers to consumers effecting repairs and classified them into three categories. Academic experts and practitioners then evaluated the importance of each barrier through a Delphi study and ranked the importance of the barrier categories. A washing machine was used as an exemplary reference. The study's findings reveal that convenience of repair (in particular, the costs of repair services and limitations in repair infrastructure) and the technical possibility of repair (lack of spare parts and repair manuals) are the most significant barriers affecting consumers' choice to repair or replace a washing machine. Given the limited literature on consumer barriers to repair, the results of this study may be used as a benchmark for testing consumer attitudes in different regions and as a reference to establish policies and repair promotion campaigns to encourage consumers to prolong the lifecycle of their products.

1. Introduction

Over the last few years, the attention given to topics related to sustainable consumption and circular economies has grown significantly (Amatuni et al., 2023). In an era of technological evolution and general prosperity, the problem of consumerism becomes more evident (Fumagalli et al., 2022): people buy new products as soon as they can afford them (McCollough, 2020). The role of consumers is fundamental in fostering sustainable consumption and determining the environmental impact of products (Sonego et al., 2022). The final decision about keeping the product or choosing to buy a new one is always made by the consumer, and is independent of how eco-friendly the product design is (Ackermann et al., 2021). Consumers' engagement and power to "vote with their wallet" are fundamental to a sustainable circular economy (CE), but consumers are often unaware of how critical their decisions may be in causing environmental harm (Spekkink et al., 2022).

Initiatives to promote Right to Repair (RtR) draw attention to the impact of waste on our planet by promoting consumers' rights to prolong product lifecycle by repairing products when needed, for example, through the network of repair cafes and do-it-yourself (DIY) repairs that make consumers more aware of their role in this effort (Moalem and Mosgaard, 2021; Sandez et al., 2023). Even though the number of such initiatives keeps growing and some firms would agree to develop products with longer lifespan under the mandatory regulations (White et al., 2021), current policies do not seem to inform and educate consumers sufficiently about more sustainable behavior (Fuchs and Hovemann, 2022).

Academicians agree on the value of repair as a product recovery strategy that can contribute to sustainability and enable CE (Bakker et al., 2014; Jaeger-Erben et al., 2021; McQueen et al., 2023). Being generally cheaper and easier to implement than, for example, remanufacture or recycling, it is surprising that repair is less investigated than other CE strategies. There is little literature exploring consumers' perspectives on repairing: very few papers address consumer barriers and the actions planned to overcome them (Terzioğlu, 2021; Sonego et al., 2022). However, exploring consumers' intentions and motives will help researchers understand how to overcome them and nudge consumers to take care of their products (Ackermann et al., 2018; Wieser and Tröger,

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2016) and hence extend their lifecycle.

To the best of the authors' knowledge, there is no common and comprehensive framework of consumer barriers to repair that defines and prioritizes the barrier categories in order to lower them. Thus, this paper aims to address this gap by setting and meeting the following objectives: (1) to systematize and classify the literature on consumer barriers to repair; (2) to evaluate the importance of barriers identified in the literature through empirical research with experts in the field of repair, sustainability and consumer behavior; and (3) to prioritize barrier categories and develop preliminary recommendations on how to tackle them.

To achieve these objectives, a systematic literature review (SLR) was performed to explore and classify the factors that make consumers abandon their products. The collected barriers were then validated through a Delphi study by assessing their importance for consumers. A washing machine was used as a reference product to make evaluations more specific. Finally, the barrier categories were ranked using the majority vote method.

The results of this paper may be helpful for academicians and provide a basis for further academic research. For example, to test identified barriers on different products and different consumers profiles, exploring the effect of social and demographical factors (Laitala et al., 2021; McQueen et al., 2023; Pérez-Belis et al., 2017; Wieser and Tröger, 2016) and cross-cultural differences (Liu et al., 2019) on repair-replace decisions. Practitioners may use this study's results to better comprehend consumers' intentions in order to design Product Service Systems (PSS) for long-term relationships with consumers (Raihanian Mashhadi et al., 2016; van Loon et al., 2020), with more focused attention paid to repair and being compliant with the environmental policies.

The remainder of this paper is organized into four further sections. The first of these, section 2, explains the methodology applied to our research. Section 3 presents the SLR on consumer barriers to repair. Section 4 discusses the results, validated through a Delphi study and a voting method. Section 5 concludes the paper and highlights some perspectives for future research.

2. Research methodology

The proposed research methodology employs three phases to identify and prioritize barriers to repair from a consumer's perspective (Fig. 1). First, an SLR was performed to identify the barriers and to classify them for a more precise presentation. Second, the list of barriers was completed and evaluated on its importance by experts through a Delphi study. Thirdly, the barrier categories were ranked according to the difficulty of overcoming them. Therefore, the paper's outcome is a comprehensive and prioritized set of consumer barriers to product repair.

2.1. Systematic literature review

Considering the relative immaturity of the literature on consumer barriers to repair, this literature review aims to provide a systematic overview of existing knowledge on the topic to create a reproducible reference for future benchmark and investigation of the effect of RtR implementation. Scientific contributions selection was performed in July 2023 and based on the intersection of the following keywords: "repair" or "right to repair"; "consumer"; "barrier" or "challeng*", or "motivat*". Scopus was the used database as it is a renowned source of engineering studies.

The combined use of keywords generated a total of 380 papers, which were then filtered by relevance based on journals, titles and abstracts. A detailed process chart for the SLR is presented in Fig. 2. This paper contains a content-based analysis of the selected articles.

The first screening phase led to the exclusion of papers on civil engineering, built environment, medicine, material and energy management through the review of titles, journals and abstracts. Detailed review of the full text (eligibility phase) led to excluding papers on impulse purchasing behavior, recycling activities, and product-service systems, which are neither specific to repair nor focused on consumers. Thus, this research is based on the studies on consumer attitude to repair, product care and product replacement (consumer needs and habits, motivations and triggers for behavioral changes in different countries), product design for repair (DfR) practices, and legislation on repairability (RtR, the EU Ecodesign Directive, the EU Action Plan for the CE, software Technological Protection Measures and other regulations that may limit or enable repair). After the keywords-based search, a retrospective approach was adopted to include the relevant studies (mainly on product design for longevity and easier repair) cited in the found contributions: this led to 26 additional papers being included in the SLR.

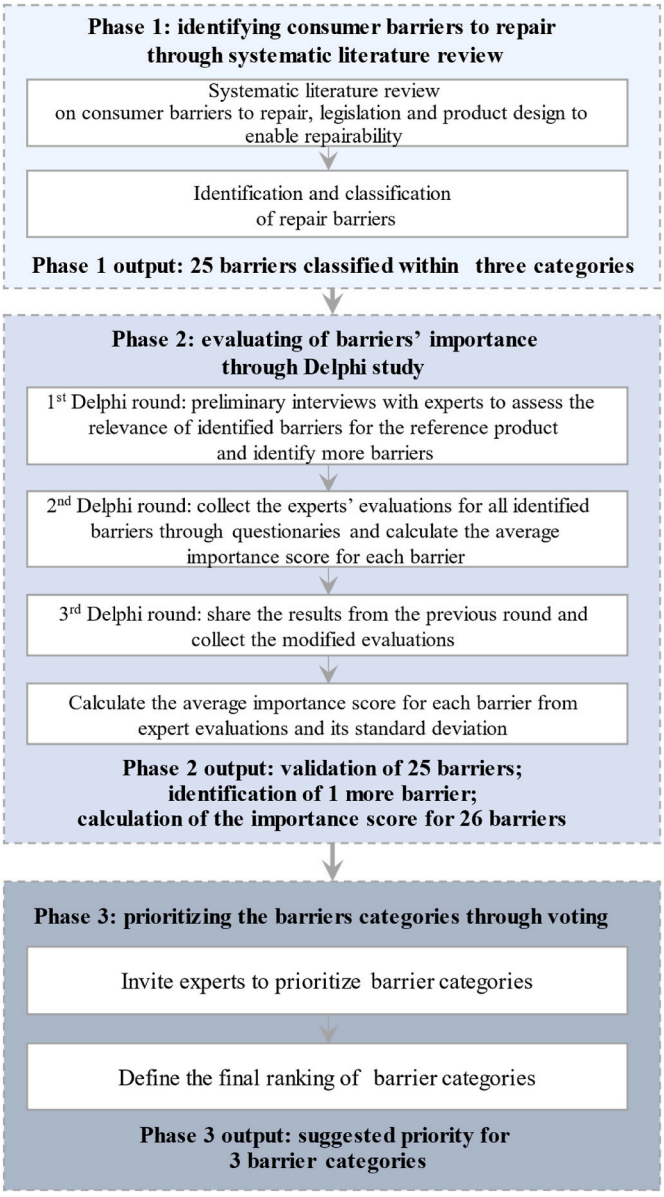

Fig. 1. Methodology followed in this research.

2.2. Delphi method

In this paper, following the example of Wrålsen et al. (2021), the Delphi method was used as a tool to structure group opinion to refine the list of barriers and estimate their importance from a consumer

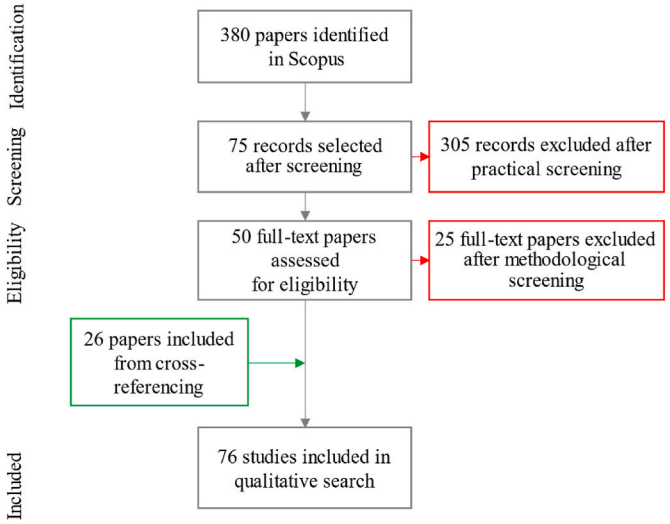

Fig. 2. Process chart for the systematic literature review (adapted from Moher et al., 2009).

perspective. Delphi allowed us to obtain judgments on the topic from an independent panel of experts, ensuring participant anonymity over several rounds and retaining significant control over bias (von der Gracht, 2012; Hallowell and Gambatese, 2010).

Although the SLR offers an initial selection of consumer barriers to repair, validation with experts seemed appropriate due to the limited number of papers directly addressing the topic. Thus, a three-round Delphi study was conducted to identify the most critical barriers to repair from the consumer's perspective. We used a washing machine as a reference product to maximize the consistency of responses when evaluating barriers' importance. We chose it for several reasons. First, it can be considered a commodity present in most family homes nowadays (Šajn, 2022). Second, it is relatively simple in terms of its function: its primary purpose is to wash cloth. This is important as it limits the variety of motivations to keep the product. For example, the multifunctionality of a smartphone (Sabbaghi and Behdad, 2018) would require a broader consideration of motivations because even if one function fails (e.g., the camera breaks), other functionalities may induce the consumer to keep it (i.e., it is still possible to make calls, send messages, pay with NFC, etc.). Thirdly, washing machines have longer technological cycles than other energy-related products, making them priority products for reuse and repair (van Loon et al., 2020). The fourth reason is related to the current regulation in several countries. The washing machine is one of the product categories that require a certification of their repairability level. Thus, understanding the consumer barriers to repair is crucial to see the effect of this regulation over time.

The Delphi panel was formed by contacting experts possessing profound knowledge in the fields of sustainability, CE, consumer behavior and repair, who work in business, academia and government institutions. Forty-four experts were invited to participate in the online Delphi study. Eighteen participated in the first two rounds, including men and women from different countries (USA, Australia, France, Italy and the Netherlands). Sixteen experts finished the third round of the Delphi study, after which a consensus in answers was reached. Table 1 presents the area of expertise, the sex, the level of studies, the years of experience in the field and the country of each expert. After each round, the facilitator asked each expert to refine his or her previous response in light of other experts' opinions, providing motivations for their choice when possible. This ensures the maximum possible consistency in defining the most critical barriers to repairing a washing machine.

2.2.1. Delphi pre-study (round 1)

The initial round of the Delphi study aimed first to validate the comprehensiveness of identified barriers to repair any product, as a result of the SLR, and then to add further barriers, following the studies of (Karam et al., 2021). The barriers were initially grouped into three categories as a result of the authors' interpretation of the SLR. In interviews, the experts were shown the current list of barriers and their categorization and were asked to review and complete it. All of the Delphi panel experts agreed on the interpretation of barrier categories and the collocation of the barriers within the three categories.

Table 1
Final round's experts' profiles.

Expertise	Sex	Level of studies	Years of experience	Country
Electronics Vendor Manager, Repair expert, practitioner	Male	Post-graduate Master	>10 years	Australia
Sustainability and repair expert	Female	PhD	5–10 years	USA
Repair expert, practitioner	Male	PhD	2–5 years	USA
Repair expert, practitioner	Male	Bachelor of Science	2–5 years	USA
CE expert	Female	Bachelor of Science	>10 years	USA
Repair expert, consumer advocacy group	Male	Master of Science	>10 years	Australia
Repair and CE expert, practitioner	Male	Master of Science	>10 years	Australia
Councilor at the Sustainable Economy, civil servant	Male	Post-graduate Master	>10 years	France
Repair expert, practitioner	Female	Bachelor of Science	2–5 years	USA
Operations Management and product sustainability, professor	Female	PhD	5–10 years	France
Sustainability and product obsolescence, institutional role	Male	Post-graduate Master	2–5 years	France
Sustainability and Consumer behavior expert, professor	Female	PhD	>10 years	The Netherlands
RtR Law, professor	Female	PhD	>10 years	Australia
Sustainability consultant	Female	Master of Science	>10 years	USA
Washing machine repair specialist	Male	Master of Science	5–10 years	Italy
Washing machine repair expert	Male	Master of Science	≫10 years	Italy

2.2.2. Collection of expert opinions (round 2)

The barriers from the first Delphi round were prepared for quantitative evaluation. The experts were asked to evaluate the importance of each barrier using a Likert scale from 1 to 6 (Table 2) and to add options if the given ones were insufficient (Wrålsen et al., 2021) or more options became available or apparent after the first discussion.

A questionnaire was developed in Qualtrics and distributed via e-mail to the invited experts. The software allowed us to ensure anonymity

Table 2
The linguistic scale used for the present Delphi study.

Rating	Linguistic variable	Scale interpretation
1	Barrier has a very low impact	Almost irrelevant
2	Barrier has a low impact	
3	Barrier has a below-average impact	
4	Barrier has an above-average impact	
5	Barrier has a high impact	
6	Barrier has a very high impact	Fundamental

among participants and to create reports easily.

2.2.3. Communication of scores and re-evaluation of barriers (round 3)

The results from Qualtrics were downloaded and elaborated, removing incomplete responses and calculating each barrier's average and standard deviation. The overall results and a personal evaluation were communicated to each expert separately via e-mail. In the third round, the experts observed the results and evaluated barriers for the second time (not necessarily changing the score). The results were communicated to the panel with a short elaboration report. So, consensus was reached as all experts confirmed their scores.

2.3. Voting

Besides validating barriers in terms of importance, the research aimed to provide indications of the difficulty of overcoming such barriers. Since some barriers are interrelated, it proved challenging to rank each barrier separately. Furthermore, ranking barriers instead of categories may have resulted in poor interpretation. Therefore, the ranking on the difficulty of overcoming barrier categories was performed. Following Hassler et al. (2014) ranking the barrier categories was based on the experts' votes in the Delphi study. Lam and Suen (1997) also confirm that a majority vote is as effective as more complicated schemes. The ranking was performed anonymously online by the experts from the last round of the Delphi study.

3. Systematic literature review: consumer barriers to repair

Many factors impact a consumer's repair-replace decision following product failure. The literature suggests some classifications of barriers and motivations based on the stakeholders involved (Sonego et al., 2022; Svensson-Hoglund et al., 2021), product and consumer characteristics (van Nes and Cramer, 2005), or the combination of external factors and consumer preferences (Svensson et al., 2018). Nevertheless, very few papers address the consumer's perspective: Ackermann et al. (2018); Lang and Armstrong (2018); Terzioğlu (2021), who analyze Fogg's model to better understand consumers' repair behavior and motivations; and Van Den Berge et al. (2022), who refer to the Theory of Planned Behavior; Fumagalli et al. (2022), who used the Compensatory Consumer Behavior Model; Dávila et al. (2021) who applied Triandis' theory of interpersonal behavior.

According to the authors' interpretation, the consumer barriers identified can be classified into three categories. First, a product must be technically repairable, meaning the product architecture should embed DfR practices (Roskladka et al., 2022). Second, the repair must be convenient: the repair services should be available and affordable, and the product's residual economic value should render it worth repairing. Third, a consumer should be willing to repair, highlighting the importance of personal motivations and social nudges.

3.1. Technical possibility of repair

Product malfunction is one of the most frequent reasons for product replacement (van Nes and Cramer, 2005). The user experience of interacting with a product and its servicing, including repair, significantly influences consumers' decisions about keeping and taking care of that product. Thus, the first category of consumer barriers to repair (Table 3) is related to inappropriate product architecture that limits the technical possibility of repair, leading to functional product obsolescence (Pozo Arcos et al., 2020).

3.2. Convenience to repair

Once the product embeds DfR principles, the next step is to motivate consumers to approach repair services. A necessary condition for this is providing affordable and convenient repair infrastructure and

Table 3
Barriers related to the technical possibility of repairing a product.

Barrier	Description and References
1.1. Access to diagnostics	Difficult error identification (Pozo Arcos et al., 2020) for electronic components and numerous hardly predictable breakdown possibilities complicate diagnostics. So does embedding software systems that do not allow users to visualize technical product characteristics that do not display malfunction descriptions (Park, 2019; Pozo Arcos et al., 2020) on the device (van den Berge et al., 2022) or through the connected app (Koverman, 2016); or that do not have an intelligent troubleshooting and repair assistant system (Sabbaghi et al., 2017).
1.2. Lack of spare parts	Restricting or controlling access to spare parts (Matarin et al., 2022; Park, 2019). Van der Velden (2021) reports that in 46% of cases, a repair is not possible due to the unavailability of replacement parts; in 20% of cases, the repair is not made because the part is too expensive.
1.3. Lack of tools	Proprietary and non-standard tools required for highly specialized types of fasteners, for example, the Pentalobe five-point screw head (Huang et al., 2016; Park, 2019; Rosborough, 2020). Sabbaghi et al. (2017) report several problems related to the quality of tools, including materials, size, absence of multifunctionality and flexibility, and ergonomic design and safety issues.
1.4. Lack of clear and complete manuals	Lack of clear and useful technical information, understandable engineering definitions, and diagrams of how to service and repair products (Hernandez et al., 2020; Huang et al., 2016; Park, 2019; Sandez et al., 2023; Svensson et al., 2018).
1.5. Safety risk	Missing safety instructions and precautions (Sabbaghi et al., 2016; van der Velden, 2021), related to electrical, chemical, thermal and mechanical risks, and the use of toxic materials (Lepawsky, 2020; Pope et al., 1998).
1.6. Product is nonmodular	Designing the product as low-configurable or monoblock, where functional parts of products are not easily accessible or undetachable; highly integrated product architecture; absence of comprehensible relations between product module and its function (Sabbaghi et al., 2017).
1.7. Complex and long dis/re-assembly	Product architecture contains many parts with very different shapes, problematic closures, glues, welding, etc., resulting in a long disassembly sequence (Hernandez et al., 2020).
1.8. Fragile materials and damage risks	Product design including low-quality or fragile materials (Godfrey et al., 2022; Nazlı, 2021), making products less robust (Bracquené et al., 2021; Shafiei et al., 2022); possible corrosion, wear, and fatigue resistance in the materials used (Aziz et al., 2021).
1.9. Digital locks	Applying repairability restrictions such as Digital Rights Management copyright and digital security systems; software locks like Technological Protective Measures; encryption; digital watermarking and tamper-resistant hardware to lock out self-repairs (Mirr, 2020; Rosborough, 2020; Sabbaghi et al., 2016). Usage terms forbidding unauthorized repairs or modification of software-enabled products (Svensson et al., 2018). Selling the devices but providing license-based software/firmware that does not give ownership rights (Arora, 2021).
1.10. Product is unopenable	Methods making it impossible to open a product without breaking or damaging it (van der Velden, 2021), such as using adhesives or soldering components (Lepawsky, 2020).
1.11. Planned obsolescence	Products being manufactured to be used for a predetermined time (Nazlı, 2021) by deliberately integrating electronic components with shorter lifecycles than a whole product (Bakker et al., 2014; Carlsson et al., 2021; White et al., 2021; Wieser and Tröger, 2016); impossibility to substitute embedded components (Lepawsky, 2020).
1.12. Impossibility of updates/upgrades	Incompatibility with state-of-the-art software (e.g., navigation maps in the car; websites to re-order

(*continued on next page*)

Table 3 (*continued*)

Barrier	Description and References
	products; updated terms and conditions), posing security risks (Wieser and Tröger, 2016), the potential loss of ability to retrieve data (Svensson et al., 2018), impeding consumers from using newly available technologies (Sabbaghi and Behdad, 2017) or the latest features of smart products (Koverman, 2016).

motivational programs. For example, Scottish government supports small shops to help locals repair (Isenhour and Reno, 2019) or Swedish NGO led nationwide repair campaign to open more DIY repair spaces (Bradley and Persson, 2022). Thus, the second category represents barriers related to the economic and practical aspects of repair. Apart from the actual costs of repair services, some papers also consider intangible costs (McCollough, 2009), such as the "search costs" of finding suitable repairing hubs and the "costs of waiting" until a product is repaired. Huang et al. (2016) cite endurance, meaning consumers getting tired of repeatedly repairing a certain product, as a time-related barrier to further repair. Moreover, inaccurate time estimation adds to consumers' frustration and annoyance with repairs. Table 4 summarizes the consumer barriers to repair related to convenience.

3.3. Willingness to repair

Sabbaghi et al. (2017) and van der Velden (2021) state that established repair infrastructure stimulates the tendency to repair. Thus, having designed a repairable product and established convenient repair services to nudge consumers to repair broken products, it is necessary to develop a repair culture built on consumers' trust (Hilger, 2016) and willingness to repair their products (Si et al., 2020; Van Den Berge et al., 2022) by helping minimize consumer beliefs about obsolescence and without compromising human well-being (Fumagalli et al., 2022). Consumer's perception of repairability and emotional attachment to a product is an important enabler of keeping products longer and repair them when needed (Maclachlan et al., 2009). Therefore, the third category encompasses the barriers related to consumers' psychological and socio-emotional dimensions (Table 5).

Table 4
Barriers related to a consumer's repair convenience.

Barrier	Description and References
2.1. Legislation and tax programs	Lack of initiatives and fiscal incentives (tax reduction) to promote repair (Rogers et al., 2021); regulatory restrictions on third-party repair imposed by manufacturers (Lepawsky, 2020).
2.2. Product economic obsolescence	Lack of economic incentives to repair a product whose functionalities may have become obsolete lead to little or no difference between repair costs and new product price (Hernandez et al., 2020; McCollough, 2009; Van Den Berge et al., 2022; van den Berge et al., 2023) which may occur due to technological evolution over time (Russell et al., 2022).
2.3. Cost of diagnostics and repair	Self-repair or serviced repair are often expensive outside warranty (Bakker et al., 2014; Mitra, 2021). Repair costs, including spare parts and labor costs (van Loon et al., 2020), dissuade consumers from repairing (McCollough, 2009). The higher the repair price compared to the replacement price, the less likely the consumer is to repair a product (Svensson-Hoglund et al., 2021).
2.4. Consumer's time for repair	Required time and effort to find a repair solution (Nazlı, 2021): "search cost" (McCollough, 2020) and waiting time (Huang et al., 2016; Sabbaghi and Behdad, 2017), including shipping time for spares (Sabbaghi et al., 2017).
2.5. Unavailability of repair services	Not enough repair services, repair cafes (Moalem and Mosgaard, 2021; Spekkink et al., 2022; Yang et al., 2023), DIY hubs (Wolf and McQuitty, 2013); or their unsuitable location.
2.6. Insufficient quality of repair services	Manufacturers' restrictions on independent repairs may lead to a reduced quality of work from independent repair services (Sabbaghi et al., 2017), although that quality is crucial to achieving consumer loyalty (Saidin et al., 2018). A lack of care, responsiveness, empathy and concern for customers during after-sales services due to short-term sales and revenue targets (Russell et al., 2022) may prevent consumers from approaching those services (Liu et al., 2019).

4. Results and discussion

The barriers derived from the SLR were collected independently of the reference industry. None of the barriers found in the literature was discarded by experts, and one more barrier emerged from the first round of Delphi. Table 6 shows the average importance score for each barrier in the three categories after the final round of the Delphi study.

The red dotted line on the table shows the average within each barrier category. It is evident that in the experts' opinion, the barriers related to Convenience are the most important, with an average score of 4.5 out of 6. This category also has the lowest standard deviation, demonstrating the alignment of the experts' judgments. The "Willingness to repair" and "Technical possibility of repair" categories have similar scores: 3.99 and 3.94, respectively. The comments of the Delphi panel highlighted that the barriers related to the product architecture

Table 5
Barriers related to the user's willingness to repair.

Barrier	Description and References
3.1. Lack of trust in repair services	Uncertainty that a repair was performed satisfactorily (McCollough, 2009; Svensson et al., 2018); perceived risk that customers may be overcharged for the repair service (Svensson-Hoglund et al., 2021); lack of trust in repaired products in general (Hilger, 2016).
3.2. Fear of further failures	Fear of emerging defects (van Nes and Cramer, 2006) and further needs for repair; failed repair attempts by consumers (Huang et al., 2016); preference to buy a new product without investing even in the first repair (Bakker et al., 2014).
3.3. Lack of attachment	Lack of emotional attachment to a product (Hernandez et al., 2020), so no difficulty in abandoning it (McNeill et al., 2020; van Nes and Cramer, 2006); being tired of a product (McCollough, 2009).
3.4. Desire for new products or features	More attractive product replacement when newer products come on to the market with superior or more "up-to-date" design features (McCollough, 2020; Wieser and Tröger, 2016) or new fashion trends arise (Lang and Armstrong, 2018), even if "artificially" recalled by producers with product-selling based business models (Kahane, 2022; Manwaring et al., 2022).
3.5. Lack of clarity on how repair works	Prejudiced belief that the product is irreparable (Wieser and Tröger, 2016); lack of knowledge about how much time the repair might take and how difficult (and costly) the repair may be (Sabbaghi et al., 2017).
3.6. Unawareness of repair impact and lack of repair habit	Lack of knowledge on repair impact; replacement morality (van Nes and Cramer, 2005); the methods and importance of prolonging product lifespans; consumers' rights; and existing repair options, attitudes and norms (Svensson-Hoglund et al., 2021).
3.7. Lack of engagement and popularization of repair	Leadership problem: lack of aware "eco-champions" (Prendeville et al., 2016), peer or media influence to raise interest and engage repairs.

Table 6
Importance score for each of the barriers to repairing a washing machine.

Category	Barrier	Added by Delphi panel	Average importance score	Standard Deviation
Technical possibility of repair	1.1. Access to diagnostics		4.25	1.3
	1.2. Lack of spare parts		5.00	1.4
	1.3. Lack of tools		3.88	1.5
	1.4. Lack of clear and complete manuals		4.75	1.5
	1.5. Safety		2.88	1.4
	1.6. Product is nonmodular		3.75	1.7
	1.7. Complex and long dis/re-assembly		4.44	1.0
	1.8. Fragile materials and damage risks		3.50	1.4
	1.9. Digital locks		3.63	1.9
	1.10. Product is unopenable		4.13	1.6
	1.11. Planned obsolescence		3.69	1.7
	1.12. Impossibility of updates/upgrades		3.44	1.3
	Average score of Technical possibility of repair		**3.94**	**1.4**
Convenience to repair	2.1. Legislation and tax programs		3.75	1.4
	2.2. Product economic obsolescence		4.50	1.2
	2.3. Cost of diagnostics and repair		5.56	0.7
	2.4. Consumer's time for repair		4.63	1.0
	2.5. Unavailability of repair services		4.75	1.2
	2.6. Insufficient quality level of repair		4.06	1.2
	2.7. Difficulty of repairing	X	4.44	1.2
	Average score of Convenience to repair		**4.53**	**1.1**
Willingness to repair	3.1. Lack of trust		3.94	1.3
	3.2. Fear of further failures		3.88	1.1
	3.3. Lack of attachment		3.75	1.5
	3.4. Desire for new products or features		4.06	1.4
	3.5. Lack of clarity on how repair works		3.81	1.4
	3.6. Unawareness		4.44	1.5
	3.7. Lack of engagement		4.00	1.0
	Average score of Willingness to repair		**3.99**	**1.3**

might mainly affect DIY repairers (Wolf and McQuitty, 2013) because most of them require technical knowledge to become relevant for all consumers.

Looking at individual barriers, the total cost of diagnostics and repair is clearly a game-changer in the consumer's decision to repair, which is also proved by other surveys run (Seyffert et al., 2018). This item also has the lowest standard deviation, confirming the alignment among experts' judgments. The second significant barrier is the lack of spare parts. Just a few experts indicated an importance score below average, stating that European Union regulations oblige manufacturers to ensure spare parts availability over the washing machine's lifecycle and a lack of parts may occur only if the washing machine is more than 10 years old. Instead, the lack of tools has a much lower score because washing machine repair mainly requires multifunctional, general-purpose tools such as screwdrivers. Next is the lack of clear and complete repair manuals and technical documentation, which hinder users' understanding of how to service the product correctly or at least determine the nature of the failure. The unavailability of repair services has the same importance score.

Regarding the consumer's time for repair, some experts highlighted the subjectivity of their score. Identifying the readiness to wait until an appointment with a technician is scheduled, spare parts arrive, and the washing machine is finally repaired depends to a considerable extent on personality and usage frequency (Van Den Berge et al., 2022). Thus, a housemaker with children may require the machine's operation daily, while a business traveler may only require it once a week or less. Attachment to a washing machine is another factor that depends a lot on the user's personality. Repair experts specify that attachment is essential for women and older people who get used to their washing machines as "servants" always ready to help. Ackermann et al. (2018) confirm that willingness to repair depends on the amount of time and effort people spend on care activities. Safety has the lowest score, even though a washing machine is an electrical appliance that circulates water (Bracquené et al., 2021). However, the Delphi panel underlines that this barrier is sensitive to the personal experience of DIY repairers. Instead, the users that will approach technicians are likely to ignore it. The

impossibility of performing updates and upgrades also received a low score as a factor related to smart washing machines. They remain a niche product, and their functionalities are not particularly desired by most consumers. Barriers like complex disassembly, the difficulty of repair, access to diagnostics, and product openability have similar scores, which may eventually translate into additional repair time and cost, so they may be of similar importance to consumers.

The invited experts ranked barrier categories to prioritize barriers according to the difficulty of overcoming them. Following this, majority voting was applied. Table 7 shows the number of votes for each barrier category for each place, with first being the easiest and third being the hardest.

Barriers related to the technical possibility of repair, being the least difficult to solve, are in first place. These barriers are primarily relevant for DIY repairers. They reflect product architecture, and thus they depend little on the consumer. To overcome them, changes in product design are required to introduce practices for longevity and easier repairability. However, designers may simply lack the expertise to design repairable products (Bakker et al., 2014) or not respect DfR guidelines (Carlsson et al., 2021; Huang et al., 2016). Indeed, some experts voted for this category as the most difficult to solve as it requires significant investments in product redesign.

Second place is almost unanimously agreed as being taken by the barriers related to repair convenience: the availability and affordability of repair services, their quality, reliability and competitiveness. McCollough (2020) highlights that repair costs are cheaper in emerging markets than in developed markets, so the perception of these barriers may vary significantly in different countries. Although the widespread presence of a repair infrastructure is fundamental to encouraging consumers to repair, their final decision will depend on their personal experience with a specific repair service. Indeed, Sonego et al. (2022), Pérez-Belis et al. (2017) and others highlight that socio-economic and cultural factors influence the search for repair possibilities. Consequently, appropriate certification and auditing of repair services would be necessary to ensure proper service and the successful engagement of consumers.

Cultivating a willingness to repair among consumers seems to be the greatest challenge. Van der Velden (2021) highlights that established and well-promoted repair servicing infrastructure would incline consumers to repair. Unlike impulse purchasing or other immediate actions to which a consumer is pushed through advertisements or other triggers, a need for repair often emerges unexpectedly. Thus, the challenge is to make a consumer remember in a moment of not (anymore) tolerated product failure that repair is a good thing to do (Wolf and McQuitty, 2013), being a convenient and eco-friendly practice. Social advertising and fostering RtR initiatives like opening repair hubs play a significant role in popularizing repair.

Fig. 3 presents the complete overview of barriers to repair, classified within the three categories from the least difficult to overcome (Technical possibility) to the most complex (Willingness to repair).

5. Conclusion

Consumer involvement and collaboration are fundamental to achieving a sustainable CE and to extending product lifecycle. Often consumers replace products before they are un-recoverable or obsolete,

Table 7
Priority votes for three categories.

Barrier category	1st place (the easiest)	2nd place	3rd place (the hardest)
Technological possibility of repair	8	2	2
Convenience to repair	0	10	2
Willingness to repair	4	0	8

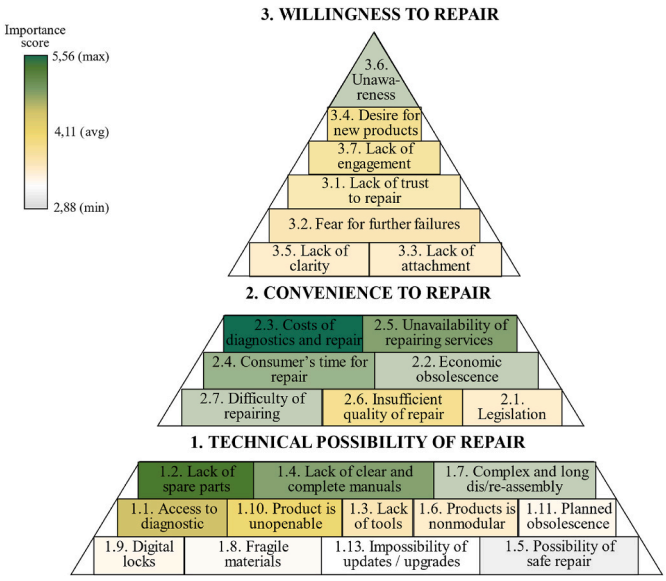

Fig. 3. Consumer barriers to repairing a washing machine, classified within three categories and ordered by importance.

leaving a harmful environmental footprint. Considering repair as an efficient product lifecycle extension strategy, this paper provides a common and comprehensive framework of consumer barriers to repair as a response to the respected gap in the literature. Through the systematic literature review and empirical studies, 26 consumer barriers to repair were identified and classified within three categories, each of which had its priority identified. The research demonstrates that costs of diagnostics and repair, lack of spare parts, repair services and repair manuals may represent the most significant barriers to repair from a consumer's perspective. Product design and repair services require reconfiguration to cope with these barriers and enable the technical and convenient possibility of repair. Developing a quantitative measurement system to estimate the level of products' repairability to guarantee its fair estimation and benchmark among products may be the next step of this study.

RtR legislation pushes manufacturers to redesign their supply chains, envisioning a CE and promoting repair among consumers. Barrier classification and prioritization may assist practitioners and policymakers in understanding consumers' perspectives regarding product treatment to develop the right approach to adapt PSS and change the consumers' mindset to embrace CE practices. Further research on social and government initiatives may enrich this study to boost consumers' readiness to repair and engage eco-leaders to foster repair. This research also contributes to educating consumers to pay close attention to the impact of their repair-replace decisions and to rethink their movement towards a "throwaway society".

Several future research directions emerge from this study. First, a test of barriers' importance for other products and its comparison with the scores identified for a washing machine would complement this study. Second, the actual consumers' perspective should be explored through a survey of a representative sample to assess the existence of different consumer profiles related to demographic factors, cross-cultural differences and social status. It would be interesting to test the moderation effect of the variables not considered in this study, such as consumers' awareness of the legislation on repair or the age of the product they possess.

CRediT authorship contribution statement

Nataliia Roskladka: Conceptualization, Methodology, Investigation, Data curation, Writing – original draft. **Anicia Jaegler:**

Conceptualization, Methodology, Supervision, Writing – review & editing.**Giovanni Miragliotta:** Conceptualization, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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