User-Centred Repair: From Current Practices to Future Design

Damla Kilic [1] and Neelima Sailaja [1]

[1] School of Computer Science, University of Nottingham

Abstract. From the kitchen to the bathroom, homes are now equipped with various technological devices like smart vacuums, intelligent mirrors, digital thermostats, wearables, and voice-controlled assistants such as Amazon Alexa. This surge in ubiquitous technologies contributes to the growing concern of electronic waste, or e-waste, globally. Research focuses on developing strategies for e-waste reduction, and is considering a range of approaches on governmental, industrial and societal levels. To gain a comprehensive understanding of smart device repair, our research was structured into several distinct tasks, each supported by semi-structured interviews, each tailored to explore different facets of repair behaviours and decision-making. A total of fifteen one-on-one study sessions were conducted as part of this research. The study's findings will be presented in three primary sections, each shedding light on distinct aspects of repair practices and decision-making. Along with the aforementioned results around current repair practices, repair decision making drivers and future expectations, our paper offers two significant contributions to human-computer interaction (HCI) research and practice. First, we place our findings in a broader context, anchoring them within the existing body of literature on HCI, repair practices, and the IoT. Second, we leverage our findings along with wider literature to conclude our paper with a set of design recommendations that align with current actual user practice around IoT repair; is inclusive of user expectations around every day reparability in future IoT; and enables user decision making around IoT repair thereby making IoT reparability an accessible and equitable process.

Keywords: IoT, consumer, smart products, repair, repair decision, right to repair, design for repair

Following ethical review, consent was not gained from participants to release personal data and interview transcripts online, and so datasets are not openly available

This submission was supported by the EPSRC Grant Number EP/T022493/1 and EP/W024780/1. Any enquiries regarding this submission should be sent to horizon@nottingham.ac.uk

1 Introduction

The transition towards an interconnected world has led to the widespread integration of Internet of Things (IoT) devices into everyday life, particularly within households. From smart appliances in the kitchen to intelligent gadgets in the bathroom, homes now feature a variety of technological advancements such as smart vacuums, digital thermostats, wearables, and voice-controlled assistants like Amazon Alexa. This proliferation of IoT technologies has heightened concerns regarding electronic waste, or e-waste, on a global scale. Forti et al. project that e-waste could reach approximately 74 million metric tons by 2030 [7].

While efforts to address electronic waste have garnered increasing attention in research circles, the focus has primarily been broad, spanning governmental, industrial, and societal levels. However, within this evolving landscape, the emergence of IoT systems presents distinct challenges to the conventional repair paradigm. Unlike traditional electronic devices, IoT systems integrate hardware, software, and data, creating a complex ecosystem that involves multiple stakeholders including users, designers, manufacturers, and retailers. This intricate network of components presents unique obstacles to the repair process. Notably, despite the growing emphasis on sustainability, the reparability of IoT devices is currently not a primary consideration for designers and manufacturers, as evidenced by existing research [4, 16]. The lack of specific attention to IoT repair highlights the necessity for future studies to explore this area in depth, uncovering the distinctive challenges and dynamics associated with repairing interconnected devices in today's technological landscape.

The aims of this paper are twofold: Firstly, it seeks to explore the evolving landscape of IoT repair by synthesizing insights from diverse academic disciplines, with a particular emphasis on the significant role HCI can play in shaping this emerging field. Secondly, it aims to present the results of a comprehensive user study designed to uncover prevalent repair practices, the key factors influencing repair decisions, and the anticipated future trends in IoT repair. The subsequent sections of this paper are organized to address the aforementioned dual objectives. In Section 2, we delve into the research landscape related to the right to repair and the decision-making processes associated with repairing IoT devices. This exploration commences with a thorough examination of multi-disciplinary literature, encompassing various facets of repair. Subsequently, we utilize this examination to underscore a distinct research gap within the current HCI literature concerning the repair of IoT devices. Moving on to Section 3, we provide a comprehensive overview of the research design formulated to address this identified research gap, employing a series of empirically supported research activities. Section 4 then presents the empirical findings derived from the study. In Section 5, we engage in a thorough discussion of our findings, drawing on existing literature for support, and propose design recommendations to the HCI community in light of our research insights.

2 LITERATURE REVIEW

2.1 Right to Repair

The "right to repair" is the principle asserting that individuals who own a product should have the ability to personally repair it or choose an expert to do so. This concept has been a subject of discourse for several decades, spanning diverse contexts ranging from automobiles to small technical devices. Over the years, discussions surrounding this right have evolved and expanded, encompassing a wide array of consumer products. This ongoing dialogue reflects the growing recognition of consumers' entitlement to access, modify, and repair the products they own, fostering a more sustainable and user-centric approach to technology. As technology continues to advance and permeate various aspects of daily life, the right to repair has become increasingly pertinent, influencing not only consumer rights but also broader considerations related to environmental sustainability, electronic waste management, and the overall longevity of products in the marketplace. Governments around the world are increasingly recognizing the importance of supporting the right to repair as a fundamental consumer right and a sustainable practice. Many countries are exploring legislative measures to empower consumers in repairing their products. This support often involves advocating for regulations that require manufacturers to provide access to repair manuals, diagnostic tools, and affordable replacement parts. In the year 2021, the UK government enacted regulations known as the Eco-design for Energy Related Products and Energy Information [3], commonly denoted as the Right-to-Repair. This initiative aimed to counteract the issue of electronic product obsolescence. Furthermore, in March 2023, the European Commission introduced a proposal advocating for the repair of goods, amending previous regulations to enhance consumer access to repair services [6]. Both sets of regulations share the overarching goal of fostering a green economy characterized by extended product lifespans, reduced electronic waste, and more sustainable design practices. Nonetheless, the focus of these regulations primarily centres on household appliances such as refrigerators, washing machines, and dishwashers, there is a growing acknowledgment that the existing rules are too narrowly framed, especially due to exclusion of smartphones and computers [11]. Therefore, even these regulations are not that old from now it is obvious that they fall short of addressing the broader environmental and social impacts stemming from the unsustainable production, consumption, and disposal of countless interconnected IoT devices [23]. The role of manufacturers in the context of the right to repair is also significant, influencing both the availability and accessibility of repair solutions for consumers. While some manufacturers have embraced the principles of transparency and consumer empowerment, advocating for the right to repair, others have been criticized for adopting practices that hinder reparability. For example, Fairphone offers consumers the opportunity to reduce e-waste and its negative impacts by purchasing specific repair or upgrade items such as the camera or screen, enabling extended phone use within the product's five to seven-year lifecycle, contributing to environmental sustainability goals [18]. However, Apple has actively opposed measures aimed at increasing the reparability of iPhones. This includes lobbying against right-to-repair legislation in various states, refusing to sell iPhone replacement parts directly to consumers, legal actions against independent repair professionals like in Norway, collaborating with Amazon to remove iPhone and MacBook refurbishes from its marketplace, and enforcing agreements with electronics recyclers that mandate the destruction of iPhones and MacBooks rather than allowing them to be refurbished [10].

2.2 The decision to Repair

While the concept of the Right to Repair is often discussed by various entities, including governments, disciplines, and industries, the decision to repair ultimately rests with everyday users. These users face numerous technological, financial, and social barriers that significantly influence their decision-making process when confronted with the choice to repair or replace a malfunctioning product. Existing literature extensively explores this multifaceted decision-making process, leading to the identification of various barriers and motivations [11, 19, 20].

Research in this area has proposed categorizations that consider stakeholders' perspectives, the intricate relationship between product and consumer attributes, and the dynamic interplay between external influences and individual preferences [22, 25, 14, 24]. Despite valuable insights from these perspectives, comprehensively understanding user behaviour in the context of repair decisions remains an evolving area with limited empirical research. Studies, including those conducted by [8, 11, 19, 20], have used consumer surveys to untangle the web of factors influencing individuals in their repair decisions, shedding light on the nuanced decision-making processes.

Roskladka et al.'s [19] recent study identifies seven significant barriers shaping a user's willingness to repair, including a lack of trust in repair services, fear of potential further failures, emotional detachment from the product, desire for novel features or products, lack of clarity regarding the repair process, unawareness of the impact of repair, and a societal lack of engagement with repair practices. Lefebvre [11] introduces a comprehensive analysis of determinants for repair decisions, emphasizing factors such as perceived reparability, available support, past experiences, attitudes, knowledge, and individual skills. However, the lack of clarity regarding distinctions between traditional and connected technology devices raises considerations about repairing various household appliances.

Russell et al. [20] extend the exploration into temporal aspects of repair, highlighting that scalability is contingent not only on technical challenges but also on temporal factors like the timing of decisions, needs, or activities. Social challenges, such as willingness to pay, physical access, awareness, and motivation, are pivotal contributors to overall repair initiative scalability. In addition to factors identified in the aforementioned studies, gender and age have been recognized as influential in repair decisions. Perez-Belis et al.'s [15] survey in Spain suggests that variables like gender and age significantly impact the repair response of small household electrical and electronic equipment (EEE). For instance, older females demonstrate a higher inclination toward repairing appliances, and gender differences are identified in the repair of mobile phones, specifically regarding concerns about data privacy related to women's phone numbers in different countries [1, 9]. These cultural nuances add complexity to understanding repair behaviours in diverse societal contexts.

2.3 HCI and IoT Repair

In recent years, Sustainable Human-Computer Interaction (SHCI) has emerged as a critical aspect of HCI, aiming to address environmental concerns and minimize the ecological footprint of technology. Mankoff et al. [13] outlined two fundamental perspectives within SHCI: sustainability through design and sustainability in design. The former emphasizes integrating sustainability principles directly into the design process, including material selection, energy efficiency, and product lifecycle management. Conversely, sustainability in design focuses on utilizing interactive systems to promote sustainable behaviours among users, such as energy conservation and responsible consumption. Despite the growing recognition of sustainability in HCI, research in this area has revealed a lack of comprehensive evaluations concerning the sustainable attributes of technology interventions. DiSalvo et al. [5] stressed the need for more systematic assessments to understand better the environmental and social impacts of HCI technologies and guide design decisions toward sustainability. Additionally, Remy et al. [18] identified five essential elements crucial for evaluating SHCI interventions, offering valuable insights into refining evaluation methods in this field. However, the absence of standardized sustainable design guidelines presents a significant challenge, particularly for complex technologies like IoT devices. As these devices become increasingly interconnected, managing their data, hardware, and software becomes more intricate [2]. Addressing this challenge requires collaborative efforts to develop adaptable guidelines that consider the unique characteristics and requirements of IoT technologies, ensuring alignment with sustainability goals and reducing environmental impact. This is a challenge that the HCI community, with its multidisciplinary, user-centred methodologies, and applied nature, is uniquely positioned to address.

In summary, the discussion surrounding the repair challenges of IoT devices reveals several notable facets. Firstly, from the government's perspective, there is recognition of the intricate nature of IoT repair, prompting attempts to address this complexity. However, current governmental endeavours to establish comprehensive frameworks for addressing the challenges associated with repairing IoT devices are still in the nascent stages. While there is acknowledgment of the need for regulation, specific and nuanced regulations facilitating effective repair practices for IoT devices are yet to be fully realized. Secondly, the role of manufacturers in supporting the right to repair IoT devices remains a topic of concern. Despite the growing emphasis on the right to repair various consumer products, including electronic devices, manufacturers have not fully embraced or implemented measures to facilitate reparability in the IoT ecosystem. The gap between recognizing the importance of repair and translating that recognition into tangible support for consumers, particularly in the context of IoT devices, underscores a notable industry challenge. Moreover, the existing body of research on factors influencing user repair decisions lacks contextualization and specificity when it comes to IoT devices. Many studies have explored various determinants of repair decisions for electronic products, but none have distinctly focused on the repair dynamics specific to the complex landscape of interconnected IoT devices [11, 19]. This literature gap highlights the need for targeted research efforts specifically addressing the unique challenges associated with repairing IoT devices, contributing to a more comprehensive understanding of the factors influencing repair decisions in this rapidly evolving technological domain.

3 Methodology

3.1 Design of the Fixing the Future Study

This research aims to address the identified gap by employing a multifaceted methodology. It involves a combination of interviews, online questionnaires, and scenario-based design to comprehensively understand participants' current repair practices and their considerations regarding IoT repair.

Semi-structured interviews are utilized to delve into various aspects of IoT use and repair. These discussions are guided by the researcher's prompts while remaining flexible to accommodate diverse responses from participants, reflecting their unique approaches to IoT usage and repair. Additionally, online questionnaires are employed to provide additional detail and depth to research-supported concepts, such as factors influencing repair decisions. Participants engage in activities within these questionnaires, such as listing and ranking exercises, to further explore and elaborate on these concepts.

To facilitate this comprehensive understanding, the study is structured into distinct tasks, each aimed at exploring different facets of repair behaviours and decision-making processes as identified in existing literature. This section provides a detailed overview of the study design and the transitions between these tasks.

Task1: The first part of the study was focused on to understand current practices of participants around repair. Therefore, participants were engaged in a comprehensive exploration of their repair experiences and practices regarding smart devices. The inquiry encompassed a range of questions aimed at delving into their repair behaviours and decision-making processes. Initially, participants were asked whether they had encountered the need to repair their smart devices. If affirmative, they were prompted to provide a succinct overview of their actions, including details about who facilitated the repair, the incurred cost, and the rationale behind opting for repair. Additionally, participants were inquired about the duration of the overall repair process and the financial investment involved. Further, those who hadn't encountered the need for smart device repair were encouraged to share their general approach to fixing household items that had experienced malfunction. This line of questioning aimed to gather insights into their broader repair practices and expenditure in situations outside the realm of smart devices.

Task2: Following an analysis of existing literature and participating in personal discussions, we established a compilation of ten factors: cost of repair services and device parts, warranty condition and original cost of the device, availability for repair, accessibility of repair services, technical difficulty, age of devices, time required for repair and physical attributes of the devices that influence their repair decision making. Throughout the study sessions, we provided participants with Microsoft Form links and requested them to prioritize these factors based on their significance while making repair decisions. In this particular section of the study, our primary objective was to delve deeper into the concerns and apprehensions of our participants when it came to the process of repairing their devices. By focusing on this aspect, we aimed to gain a comprehensive understanding of the various factors that influenced their decision-making in this context. Through this exploration, we sought to uncover nuanced insights that could shed light on the underlying motivations and considerations that guided their choices regarding device repair.

Task3: Within this specific segment of the study, we introduced five distinct scenarios, each centred on a different category of smart devices: Smart Watch, Smart Speaker, Smart Thermostat, Smart Toy, and Smart Washing Machine. These scenarios encompassed a range of situations, including considerations such as device pricing when received as a gift or purchased second-hand, alongside limited details regarding the nature of the device fault. The smart washing machine scenario is shown below as an example.

> "You purchased a top-of-the-line smart washing machine for your home (1250 GBP), but you decided not to buy the warranty offered by the manufacturer because of its high cost. You thought that since the washing machine was expensive and of high quality, it would be unlikely to have any issues. For the first few months, the washing machine worked perfectly, while doing laundry, you noticed that the machine was making strange noises and wasn't draining the water properly. "

Participants were tasked with reading each scenario and making decisions about five distinct factors associated with repairing the defective items. Specifically, they were required to indicate: (1, 2) The amount they were willing to allocate for repair services and the cost of the device part. (3) The age until which they were willing to continue repairing the devices. (4) The level of technical difficulty they were comfortable with in repairing the devices. (5) The duration they were prepared to wait for the repair of these items. By presenting participants with these diverse scenarios, we aimed to simulate current and future real-world scenarios around repair and gather insights into their decision-making processes, towards different devices and different factors.

Task4: In an initial endeavour to gain insights into the forthcoming landscape of repair practices, we presented participants with a set of 10 distinct hardware and 10 software issues encompassing various smart devices (Please see the Table 1). Participants were tasked with making informed decisions about their preferences or anticipated choices for repair approaches in the future. The range of repair options spanned a spectrum, including Individual Repair, Individual Repair supported by online resources, Repair Cafes, Independent Repair Shops, Manufacturers (such as Amazon or Apple), Professional Repair Services (like iCracked or uBreakiFix), and Warranty Services offered by third parties outside the original manufacturers. This phase of the study was structured using the Miro platform. The researcher utilized Microsoft Teams to share her screen, adhering to the participants' guidance for each unique scenario presented.

Table 1. Hardware and Software Repair Scenarios

S1: Your wearable health tracker starts generating unexpected or incorrect data about your physical activities. What will you do?
S2: Your smart shoes may not be able to sync with the companion app, preventing the user from accessing up-to-date fitness data. What will you do?
S3: Your wearable health tracker may become damaged, and it results in cracked screens. What will you do?
S4: Your brand-new smart shoes have the battery problem, and this results in reduced functionality. What will you do?
S5: If your smart washing machine run endlessly or repeatedly start and stop without completing a cycle. What will you do?
S6: If you have programmed your robot vacuum cleaner to clean every Saturday morning around 10 am, but the device starts cleaning at 3 am while you are sleeping. What will you do?
S7: When a smart washing machine experiences mechanical issues such as a broken belt, pump, or motor. What will you do?
S8: If your robot vacuum cleaner is having trouble navigating around obstacles and getting stuck in tight spaces or corners during your cleaning routine. What will you do?
S9: When your CCTV is having trouble connecting to your Wi-Fi network or other devices in your home. What will you do?
S10: If the thermostat is giving inaccurate temperature readings and lead to waste of energy. What will you do?
S11: When you realized that your smart thermostat is hacked, and your login credentials, financial information, or other sensitive data are under risk. What will you do?
S12: Your smart CCTV may be affected by harsh weather conditions, such as rain and not working properly. What will you do?
S13: When you realized that your children`s smart doll is collecting and transmitting sensitive user data (such as their reading habits) without proper security measures in place. What will you do?
S14: If you discover that, despite having enabled parental controls on your children's educational tablets, they are still able to access web pages that are not part of the approved content. What will you do?
S15: If the sensors on your children's smart dolls are not working correctly, and the doll is unable to respond to requests to perform physical actions. What will you do?
S16: When you realized that your children`s educational tablet have a cracked or unresponsive screen sometimes in a day. What will you do?
S17: When you ask anything to Alexa, it provide inaccurate or irrelevant responses. For example, when you ask a recipe of carrot cake, it tells you about the weather in the UK. What will you do?
S18: The Chabot that you use daily is leaking user data to unauthorized third parties. What will you do?
S19: You realized that your Alexa cannot accurately recognize voice commands. It may be because of microphone of your Alexa is not functioning properly. What will you do?
S20: Your smart speaker may not respond to button presses to turn it on/off. What will you do?

3.2 Participant Recruitment

Recruitment of participants was carried out through a combination of a mailing list and social connections. As an incentive for their involvement, participants received a modest payment of £15 amazon voucher each. Eligibility criteria included being at least 18 years of age and owning a minimum of one smart device.

A total of 15 participants took part in the study, representing a variety of occupations and household statuses. The participants encompassed a diverse group, including students and researchers spanning a wide array of disciplines ranging from computer science to food sustainability. Out of the 15 participants, 7 were married, while 6 identified as single. The number of household members for the participants varied, ranging from 1 to 5 individuals. Regarding house status, the participants were categorized into three groups: homeowners, renters, and those living in student accommodations. Also, approximately 9 participants reported an income of less than 35,000 GBP.

3.3 Data Collection and Analysis

The research was conducted using Microsoft Teams as the platform for fieldwork. Ahead of each study session, a welcoming email along with a reminder was sent to a member of each household participating in the study. This email contained the Microsoft Teams meeting link and provided clear, detailed instructions on how participants could easily join the meetings. Also, Microsoft Forms and Miro were actively utilized throughout the sessions to enhance participant engagement in various parts of the study. Ethical approval for this research was obtained from the Ethical Committee of the Computer Science Department at the University of Nottingham. Participants engaged in the study by utilizing their personal networked devices, typically within the comfort of their own homes. The study sessions occurred from February to July 2023, with each session lasting approximately 50 to 70 minutes. The data gathered during the study comprised audio recordings of conversations between participants and researchers conducted through Microsoft Teams. Subsequent to transcribing the recordings, the researcher removed the names and any direct identifying details of the participants from the interview notes and transcripts.

4 Findings

The study's findings painted a vivid picture of the technological landscape inhabited by our participants. All 15 individuals showcased an impressive array of smart devices, including but not limited to energy-monitoring smart plugs, smart heating controls, robot vacuum cleaners, security cameras, Wi-Fi-enabled air purifiers, well-being health trackers, smart TVs, and voice assistants like Alexa and Google Home, not to mention the ubiquity of smartphones, tablets, and laptops tailored for varied tasks and research. Beyond merely owning these devices, the participants deeply integrated them into the very fabric of their daily routines. Voice assistants like Alexa were no longer fancy gadgets but had become virtual household members, assisting with weather updates and setting alarms. Smart heating controls weren't just about warmth but symbolized energy efficiency and remote convenience. Devices like Google Home took on the mantle of a digital caretaker, fine-tuning home ambiances with tasks such as lighting adjustments and musical accompaniments. As the discussion shifted to the control mechanisms of these smart devices, a common theme emerged: participants often intertwined the use of physical controls with mobile apps to orchestrate their technological symphony. Voice control, facilitated effortlessly by Alexa and Google Home, was underscored by many as the epitome of convenience in this smart era.

4.1 Current Practices around repair

Exploring the repair practices of our participants unveiled a fascinating tapestry of experiences, spanning a spectrum of devices from modern smart products like smart washing machines, smart TVs, Fitbits, robot vacuum cleaners, smartphones, laptops, headphones to older, traditional technologies fridges, freezers, and televisions. To illustrate, they recounted experiences with fixing

Common smartphone issues included broken screens, as faced by P1 and P14, and charging port malfunctions, a challenge for both P2 and P6, with the latter highlighting complications due to the device being a less-known brand in the UK. Smart appliance troubles were highlighted by P2 and P8, who both dealt with smart washing machine hardware and software breakdowns. Meanwhile, robot vacuum cleaners, as noted by P15 and P14, presented challenges too. While P15's issues were more hardware-centric, P14 grappled with software-related mapping issues, necessitating a remapping of his house layout.

On the traditional front, P5 pinpointed a washing machine electronic board malfunction, P6 discussed issues with a fridge and manual washing machine, and P15 creatively addressed a latch problem on a non-smart vacuum cleaner.

4.2 Decision making around repair

One of our study's primary objectives was to delve into participants' decision-making processes concerning faulty items – whether they chose to repair or disregard them. By exploring participants' experiences with malfunctioning devices, we aimed to uncover their troubleshooting strategies. Typically, participants would first assess the gravity of the malfunction and its effect on their daily operations.

Here, there were instances where participants chose to live with minor glitches in their devices. P4 overlooked smart vacuum cleaner inaccuracies, P9 accepted a persistent digital camera issue, and P11 endured laptop problems before ultimately replacing it. Minor glitches often saw participants adopting a DIY approach, turning to a slew of online resources like forums, user manuals, helplines, Google, YouTube, and technical blogs to guide their repair efforts.

Yet, when issues became more intricate or surpassed their skill set, participants adopted a more collaborative strategy, reaching out to tech-savvy friends for advice. This network often provided varied solutions and insights. In unresolved cases, formal repair avenues became the focus – this could be third-party services, manufacturers, or local experts. Some participants even mentioned community-known individuals adept at troubleshooting, affectionately referred to as "that man" or "our repair guy."

P3's experience perfectly encapsulates this methodical approach. When things go wrong with her smart devices, P3 follow a step-by-step plan. First, P3 figures out how bad the problem is and how much it messes up my daily use. If it's a small issue, she tries to solve it herself. P3 search online to learn what's causing the trouble and if she can fix it by reading and understanding. But if the problem is bigger and makes a big mess of my gadgets, she switches to asking for help. She talks to people she knows who might know more about these things than him. It's like asking a friend who's good with tech stuff. This way, she gets different ideas and solutions. So, when something goes wrong, she starts by checking it out himself. If it's too much, she asks people who know more. It's like a team effort to get things working again. And if things are still a mess after that, she looks for more technical help. She might check out company websites or technical blogs, but that's not his first go-to. She tries to keep it simple and stick to Google and YouTube mostly. So, she guesses you could call it a "try it yourself, ask friends, then get technical" process. It's like when you're trying to build a puzzle – you start on your own, ask a friend for help if you're stuck, and then maybe ask an expert if you still can't figure it out.

4.3 Responsibility of repair decision

Social repair dynamics presented themselves across a range of approaches that spread between individual autonomy, collaborative efforts and shared responsibility.

P1 assumes repair responsibility within their household due to their family's composition and their comprehensive understanding of gadget insurance terms, which empowers them to effectively manage repairs. Their role as the repair person is influenced by both family dynamics and their specialized knowledge of insurance provisions.

P9 and P14 illustrated how a mix of autonomy and teamwork guided their repair decisions alongside their partners. P9' mentioned that *"It's shared responsibility and I'm quite autonomous in that sense."* Here, a balance was struck between individual autonomy and shared decision-making. P14 echoed a similar sentiment, highlighting a collaborative attempt at repair while ultimately embracing individual responsibility.

P6's household revealed a shared responsibility for repairs, often undertaken by the participant's father or their own expertise as a physics teacher. Also, P4 and P7 exemplified the influence of interest and expertise, stepping forward as primary repair figures due to their familiarity with repair tasks and household systems. Additionally, P5 and P6 contributed to our understanding of shared responsibilities within households. P5 disclosed, *"My brother is very good with laptops... between the two of us we try to resolve what we need to resolve."* This collaborative dynamic illustrated the collective effort to address repair issues, leveraging the strengths of different family members.

However, others, like P2, divided responsibilities practically, with certain family members handling hands-on tasks while others tackled tech-related issues. P2 stated that *"If something broke, it would be either me or my dad that would fix it. If it's something more practical, like water or something that needs a power drill, it's usually my dad and although I have those skills as well, whereas if it's something technological like a computer or TV, if they wanted it, fixing it would come to me".* This approach underscored the interplay between technical proficiency and hands-on skills, with specific individuals stepping up based on practical considerations.

4.4 Key Drivers of Decision Making around Repair

The most common factors influencing decision making around repair are the cost of repair (P5, P7, P10, P11), age of devices (P2, P11, P14) and time taken to repair (P2, P5, P9). P2's perspective, as articulated in the following quote, underscores that alongside the *cost of repair,* the *age of the device and time taken to repair*, other factors such as the *personal value a device holds* in one's life plays a pivotal role in shaping the repair or replacement decision:

> P2: Let's say, my TV is worth, I don't know, £300, and it would cost £150 to repair it. My TV is now 12 years old and has been with me across three cities and 12 houses. At this point, I would probably just replace it. However, if it were my computer, the value of my computer is far more than what it actually costs. It's probably only worth £700 these days because the parts are so old. But because I use it every day and it has all of my stuff on it, I would happily pay £400 or £450 before I even thought about replacing the whole thing.

Formative phase of the decision

Participants listed different factors that they consider before (and those that thereby influence) their actual repair decision making: *Their mental and physical capacity to sit down and work out how to repair the devices* (P2), *who you trust to repair* (P3), *whether the device is first or second-hand* (P4), *warranty status of the devices* (P5,) *accessibility of the device's spare parts in different countries* (P6, P11, P15) and *how confident the users feel to fix the problem themselves* (P9). Moreover, the intended user of a device emerged as a significant determinant influencing the decision to pursue repair. P7 illustrated this with an example: when dealing with devices intended for the entire household, such as central heating control systems, the inclination to invest time in perusing online documentation, reading forums, or watching instructional videos on platforms like YouTube diminishes.

Process of the decision

In terms of prioritizing the ten distinct factors influencing the decision to repair or not among the participants, at the forefront of their considerations was the ***cost of repair services***, a pivotal determinant in their choices. Directly followed by ***the cost of device parts***, carrying significant weight in the decision-making process. The ***warranty condition of the device*** held its place as a key aspect, influencing choices considerably. The ***original cost of the device*** emerged as an influential factor. If the original cost of the device is lower, P9 believes that it is often more practical to consider replacement over repair. They emphasize that affordability plays a significant role in their decision-making process. For items that are relatively inexpensive to replace, P9 tends to view repairs as less cost-effective and time efficient. However, they also acknowledge that for high-value items such as a car, where repair costs may be substantial but still less than the expense of buying a new vehicle, the repair option becomes more appealing. ***Availability for repair*** followed closely in importance, with participants giving it serious consideration. The ***accessibility of repair services*** also played a notable role. The perceived ***technical difficulty*** of the repair task influenced decisions, with participants tending to favour tasks they felt competent to handle. The ***age of devices*** had low impact on participants` decision making. When discussing the importance of a device's age in the context of repairs, one participant, P8, emphasized that age alone is not a decisive

factor. They pointed out that the significance of the device's age hinges on other variables. Whether a device is expensive and relatively new or an expensive one that has aged, P8 stated that they would assign it the same level of importance when considering repairs. The ***time required for repairs*** ranked lower in the hierarchy of importance. Finally, ***the physical attributes of the devices***, such as size and weight, were the least significant factors when it came to repair decisions. P11 expressed the perspective that when a device requires repair, its size becomes inconsequential.
As delineated in the methodology section, beyond exploring the factors influencing repair decisions, one of the other aims of our study is to delve into participants' repair choices across various devices (Please see Figure 1 below).

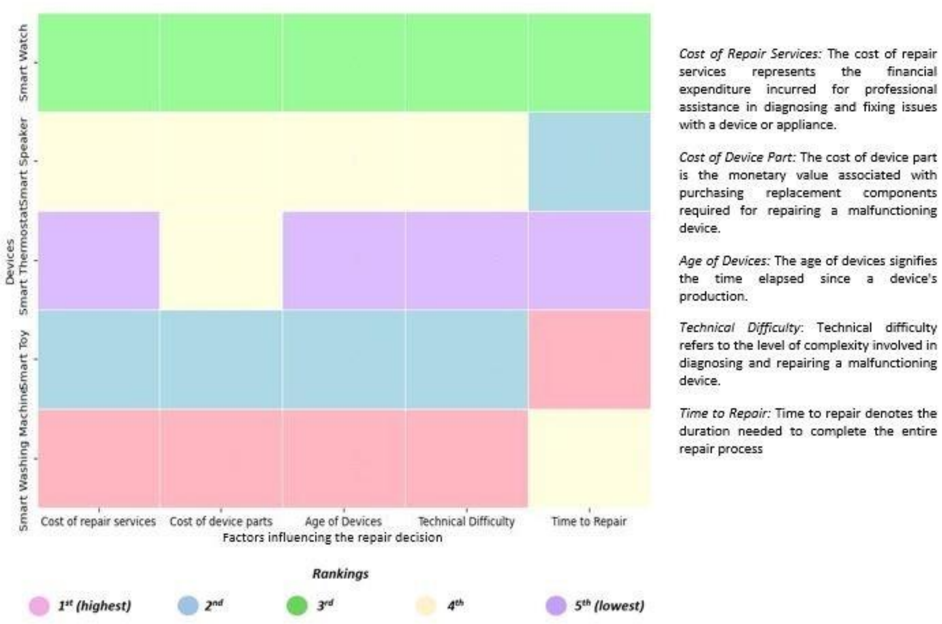

Figure 1. Devices and factors influencing the repair decision

Participants expressed varying preferences depending on the type of device in question. They mentioned considering different factors at the same time and trying to come up with a final thought is challenging. One of the participants stated that she is trying to find a good balance between all the factors. The price of the Thus, the figure provided herein displays five distinct devices alongside participants' rankings regarding five different repair-influencing factors. The color-coding adjacent to the table denotes rankings, with pink indicating the highest ranking and purple indicating the lowest. The price of the device, the people involved, the purpose of the device, whether it was first hand or second hand, and whether you had the warranty were all considered among a lot of different factors (P3).

Upon closer examination of the findings presented in the table above, it becomes apparent that, for instance, concerning washing machines, the majority of participants expressed a willingness to invest more in both repair services and the necessary parts for repairs. Additionally, participants anticipated that washing machines, given their crucial role in household functioning, might have a higher age and technical complexity compared to other devices. However, given the essential role of washing machines in maintaining household operations, participants were reluctant to endure prolonged repair durations, emphasizing the need for timely resolution to ensure the continuity of household services. As one of the participants put it with respect to washing machine (P2), for example:

> P2: I think I would be willing to pay more to get the washing machine repaired and obtain the reports. And again, with the assumption that I would want it to last at least five years for the washing machine. So, if I could repair it and it could last that long, I'd happily spend the money. Whereas if it was just going to be a temporary fix, I wouldn't. Um, but I would want it back immediately. You know, I'd really struggle to send it off, as it would suck to live without a washing machine since there are 6 adults there, a baby, and a dog, and it would be awful. So, I'd want it back immediately. And if it couldn't be fixed really quickly, then I would replace it because it's a necessity to have it for me

In contrast to washing machines, the smart thermostat, despite being a household device, does not hold the same level of significance for our participants when considering repair. Our participants consistently gave the smart thermostat lower ratings across all five factors influencing repair decisions. One participant highlighted the distinction between these two devices:

> Researcher: What about smart thermostats and smart washing machines? We use them daily, but are they equally important to you?
> P15: Yeah, I wouldn't say so. I can live without knowing the temperature of my home. I can measure it manually if I really need to. But yeah, it is less important. However, for the washing machine, it's quite important.

This differentiation in perceived importance sheds light on the varying attitudes participants hold towards repairing different types of smart devices within their households. Moreover, when contemplating various devices in diverse situations, participants also raised the subject of emotional attachment to these devices and how this attachment influences the factors they take into account when deciding whether to repair them. This discussion highlights the profound personal connection individuals have with their devices and how this emotional bond plays a pivotal role in shaping their repair-related considerations and choices, illustrates P13 with respect to smart children toy:

> P13: The children's toy holds an emotional connection. I just think about it this way: my child may be very attached to that specific toy, and you know how children can be – they often need that exact same toy. So, yeah, I'm willing to pay whatever it takes, I'm willing to wait, and I'll do whatever I can to ensure it gets fixed and returned to the child.

4.5 Current and Future of repair and expectations

In fact, 14 out of the 20 scenarios revealed that most participants shared similar preferences when it came to their favoured repair approach (please see Figure 2 for more information). This consistency in preferences suggests that certain factors or considerations strongly influence participants' decision-making processes. Therefore, in the remaining part of this section, we will delve deeper into the practical and everyday reasoning of our participants that emerged as they discussed their preferences.

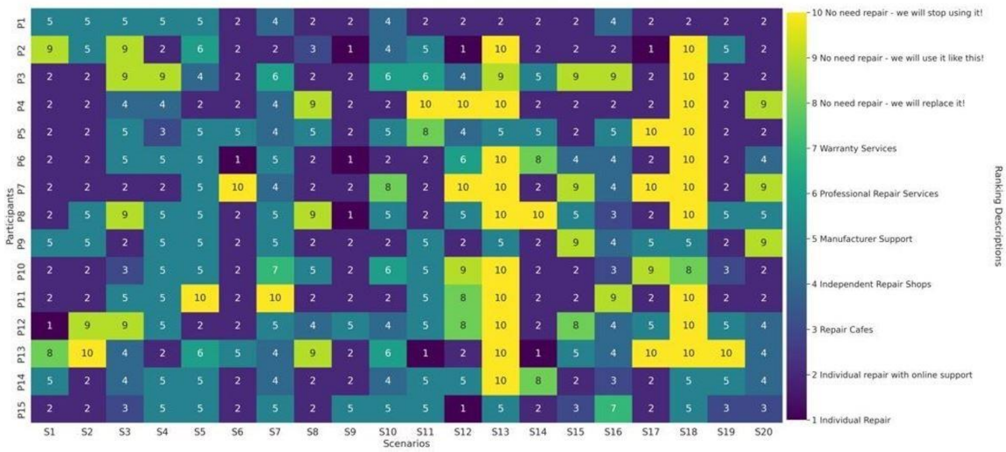

Figure 2. Spectrum of the Repair

Self-Repair

In 8 of the 20 scenarios presented (as evidenced in Figure 2), participants leaned towards self-repair with online support, such as YouTube videos or websites like iFixit. While varied reasons drove this choice, some common factors emerged. For example, *past experience* with a similar issue often gave participants the confidence to handle the repair themselves. For example, P9 had prior experience of fixing a cracked screen on her wearable health tracker with the aid of online tutorials. Participants also leaned towards individual repair with *online support* due to the prevalence of shared experiences on common issues. They believe that the ubiquity of a problem often leads to a wealth of insights and solutions available on various online platforms. The shared collective wisdom, often detailed on websites, forums, and social media, instils confidence in individuals facing similar issues, encouraging a DIY approach to repairs.

Participants who preferred online support for self-repair also often chose websites, forums, and general web searches over brand-specific applications. They expressed concerns that individual apps for different devices and brands could lead to clutter and inefficiency. As P5 elaborates, "When I face a technical issue, I first look for solutions on user forums or online communities," a sentiment rooted in the practicality and accessibility of real-world advice and solutions. This gravitation towards peer insights underscores a communal level trust, where real-life experiences are deemed more valuable than official manufacturer guidance, as P8 echoes, *"Manufacturer manuals are often too technical... I prefer watching YouTube videos where someone walks me through the troubleshooting process."*

Seeking support for more 'complex' repairs

Our study participants frequently associated the complexity of a problem with their level of prior experience in troubleshooting and repair. In essence, if they lacked prior experience in addressing a particular issue, they were more inclined to label it as a complicated problem. For instance, if a smart washing machine exhibited behaviour such as running endlessly or repeatedly starting and stopping without completing a washing cycle, participants commonly regarded these symptoms as indicative of a complex issue (P3) and emphasized the need for expert guidance (P1). Hence, it is noteworthy that the majority of our participants, specifically 9 out of 15, expressed a preference for reaching out to the manufacturer's support as their initial contact point when faced with software problems in their smart washing machines. Other examples are, encountering a battery issue with brand-new smart shoes or realizing a smart thermostat has been compromised, putting sensitive data at risk. In these situations, the manufacturer is seen as the most reliable resource for assistance. The tendency to seek help from the manufacturer highlights the significant level of trust users have in the companies that create these products, particularly for resolving software and security issues. P5 echoed this sentiment, emphasizing the value of the manufacturer's support due to their intimate knowledge of the product and an inherent obligation to assist their customers, underscoring their accountability for the products they produce.

Social anxiety emerges as another factor affecting the decision to repair as it is influenced by the communication preferences of participants when seeking repair support. The aversion to direct phone conversations is identified here, with participants like P11 articulating, *"I don't want to talk to someone on the phone, but I would be happy to chat to customer support."* This inclination towards text-based interactions underscores the nuanced role of social dynamics in shaping engagement with support services.

Not choosing to repair

Certainly, repair does not always represent the chosen course of action for our participants. At times, participants deemed certain device malfunctions too critical to even attempt a repair. Instead, they chose to discontinue its use entirely.

Participants were happy to have reduced functionality and use the smart devices without smart future of it. Instead of having smart watch, P2 is happy kept using it as a watch, if the wearable health tracker starts generating unexpected or incorrect data about their physical activities. P13 provides another reason for participant to prefer not choosing to repair:

> P13: If health tracking is very important to me, I would say there is no need to repair it. I'll just replace it because when it comes to health, accuracy is crucial. You need something that provides correct information, especially since health data is very sensitive. So, I prefer

> to have a brand new one that's working perfectly rather than a repaired one that might still provide inaccurate information

Furthermore, participants exhibited similar attitudes towards issues such as reduced battery life in smart shoes (P3) or synchronization problems with companion apps (P12, P13). Additionally, instances were noted where participants discovered privacy concerns with certain smart devices, such as a child's smart doll transmitting sensitive user data insecurely (P2, P3, P4, P6, P7, P8, P10, P11, P12, P13, P14), or a chatbot inadvertently exposing user data to unauthorized entities (P2, P3, P4, P5, P6, P7, P8, P10, P11, P12, P13, P14).

Lastly, sometimes the decision to repair or not is dependent upon the context, culture and resources available. Some participants expressed that in urban environments, accessing repair services was straightforward, as opposed to rural settings, where repair resources, services and alternatives might be scarce. P10 shared their perspective, contrasting their current urban living situation with an upcoming move to rural Malaysia, where repair resources might be less accessible.

5 Discussion

As stated in the literature review section, our findings also emphasized that the repair decision-making process is complex, influenced by various factors that emerged in distinct contexts within the study. Factors influencing repair decisions varied among participants and malfunctioning devices, but the most common included cost of repair, age of devices, and time of repair. Similar to general technological devices, our study indicates that users evaluating IoT devices take into account factors such as their ability to perform repairs, trust in repair sources, device condition (first or second-hand), warranty status, parts accessibility, confidence in personal repair skills, and the intended user of the device.

Building upon the research by Roskladka et al. [19], we extended our inquiry to explore participants' repair attitudes towards a diverse array of smart devices, including Smart Watches, Smart Speakers, Smart Thermostats, Smart Toys, and Smart Washing Machines. Contrary to the notion that repair attitudes may be specific to certain device types, our findings indicate a nuanced adaptation of decision-making strategies based on the device's nature and specific usage scenarios. For instance, participants demonstrated a greater willingness to allocate resources towards repairing essential household devices like washing machines, driven by the imperative of household continuity. However, this commitment to repair was tempered by a reluctance to endure prolonged repair durations, highlighting the delicate balance between practical necessity and inconvenience. Furthermore, our investigation revealed the significant influence of emotional attachment to devices on repair decisions, particularly evident in scenarios where participants considered the sentimental value associated with certain smart devices. As exemplified by P13's experience with a smart children's toy, emotional connections to such devices can often outweigh purely pragmatic considerations, complicating the decision-making process. This underscores the multifaceted nature of repair attitudes and the need for a holistic understanding of users' emotional and practical motivations in navigating repair decisions across various smart device categories.

In conjunction with the literature highlighting age [15] and gender [1, 9] as influential factors in repair decisions, our study extends these considerations to repair responsibilities within households. Additionally, we unveil a range of household-specific factors that impact repair decisions among participants. One such factor is the expertise level of household members in handling different types of repair tasks. While some individuals may excel in hands-on tasks, others may be more adept at tackling technical issues related to devices. This division of labour based on skillset contributes to the allocation of repair responsibilities within households.

Furthermore, social dynamics within the household, such as parental responsibilities and financial situations, play a crucial role in shaping repair decisions. For instance, individuals may prioritize repairs differently based on familial obligations or budget constraints. Additionally, repair decisions often involve collaborative efforts among household members, with discussions and negotiations taking place to determine the most feasible course of action. These social dynamics add layers of complexity to the repair decision-making process within households, reflecting the intricate interplay of personal, familial, and financial considerations.

Also, the role of manufacturers concerning the right to repair holds significant importance [10, 18]. While some companies actively contribute to sustainability efforts by offering repair options and reducing electronic waste, others oppose right-to-repair legislation and restrict repair opportunities for users. However, there remains a gap in research regarding the specific areas where users require manufacturer assistance and their underlying concerns in this regard. In our study, we delved into this aspect and uncovered valuable insights. Participants in our research demonstrated a clear correlation between the perceived complexity of a repair issue and their level of prior experience in troubleshooting and repair. When faced with unfamiliar or intricate problems, participants tended to view them as more challenging and sought expert guidance. Notably, for issues such as software problems or security breaches, participants expressed a preference for reaching out to the manufacturer for support. This preference underscores the substantial trust users place in manufacturers to effectively address product issues. Participants emphasized the value of manufacturer support, citing the company's intimate knowledge of the product and their perceived responsibility to assist customers. These findings shed light on the critical role of manufacturers in providing technical support and assistance to users facing complex repair challenges. Moreover, they underscore the accountability of manufacturers in ensuring the functionality and longevity of the products they produce. Moving forward, further research in this area can help elucidate users' specific needs and concerns regarding manufacturer assistance, contributing to more informed policy discussions and industry practices related to the right to repair.

5.1 Design recommendations

Based on the above empirical study and its resulting findings and discussion, we propose a focused set of recommendations to the HCI community, who is positioned uniquely in terms of it multidisciplinary which brings together computing, design, education and policy. These recommendations are set forth to be taken up by researchers, designers and developers aiming to embed reparability as an inherent property into future IoT making, management and maintenance. These recommendations, derived from actual user wants and needs unveiled in the study, when applied, become a practical and tangible set of guidelines that would help support the users' with their everyday repair decisions and processes.

Making the process of troubleshooting easy, quick and accessible: Helping the user quickly understand what is wrong with their device, the alternatives available for fixing it and the expense (time, money and effort) the process entails become an important necessity that is currently underserved. This needs to be responded to so that the users are informed enough to make decisions around the next steps of who to contact, what spare parts or tools to access, the most efficient and effective pathway to getting their device repaired etc. HCI research, through its user centred approach and design led methodologies becomes the premier pathway to solutions in this scope which calls for responses that distil large knowledgebase around repair to the focused and user-friendly interventions that this gap seeks.

Effective use of multi-media: To allow for effective dissemination of repair related information, a call to move away from just text based instructional guides is highlighted. Here, we see a need for a mix of media, from audio-based call support or conversational agents to instructional videos to detailed specification documents, each designed to suit a different kind of user and their unique contexts and needs around repair. To understand user contexts around their optimal media type and the very design and dissemination of the instructional asset through this media requires meticulous user centred research, yet another challenge the HCI community should undertake.

Regulated online communities: Where official support is not often prevalent, users turn to post-official communities, Facebook groups and other social media forums that support the repair of their devices. But being unregulated, the trust in these measures would be less than if such communities for repair support are maintained in conjunction with manufacturer stake. This would help with access to official documentation, more accurate recommendations and mitigation of risks from unofficial repairs which could prove harmful if done by inexperienced users. Bringing together the interests of multiple stakeholders, prioritising the user requirements and developing novel strategies for computer supported co-operative work that enable this emergent landscape of technology circularity through repair are challenges that need a holistic, yet multi-disciplinary and applied intervention, all of which speak to the HCI ethos.

Access to manufacturer: Currently, repair as an alternative to replace stays very weak due to the lack of support from manufacturer side. To move away from this status-quo to one that actively enables repair requires multiple avenues of connection between the manufacturer and user. This could be through direct customer support, manufacturer regulated communities and forums, manufacturer whetted instructional resources or even manufacturer enabled processes for quickly assessing a fault, acquiring legal and appropriate spare parts etc. HCI, being the host to several research domains identified here (online communities, computer supported co-operative work, interaction design and user-centred research) would be the perfect point of amalgamation of these priorities to support the realisation of a technology future where repair is live through an active system of communication and collaboration between the key stakeholders of a circular (technology) economy.

Equal responsibility through empowerment: Our findings show a spectrum of responsibility levels around repair decision making and actions. These variations are often socially derived and a reflection of lack of resources and support that cater to a more diverse set of all backgrounds and contexts. Within families and co-located situations, we see a dependence on certain individuals who are assumed to have more knowledge and experience. On a wider scale, we see reports of a complete lack of access to repair resources depending upon the geographic location. This social divide that exists on a global scale seeks to be alleviated, for which future design needs to look into alternatives of empowerment through open access to repair information, more accessible knowledge assets, modularity in device design, transparency of software architectures and more inclusive efforts towards maintenance and repair initiatives. Understanding equitability challenges at several levels of the social system (from the home to a global scale) is a herculean challenge that requires a combined effort from social science, psychology, computing and design together to explore the landscape, explicate the nuances at each level and expound responses that speak to the myriad different contexts across layers. Here, again HCI being a hub for these very domains, along with its methods that render it capable to work at the different social strata, with different sets of stakeholders and their corresponding situations make HCI a key player in the near future of reparability research for technology and beyond.

6 Conclusion

In conclusion, our study sheds light on the intricate factors influencing repair decisions for IoT devices, particularly within households. We've highlighted the importance of economic, emotional, and practical considerations in repair choices, emphasizing the role of factors such as device age, household repair expertise, social dynamics, and manufacturer support. Proposing design recommendations for the HCI community, we advocate for embedding reparability into future IoT devices and promoting user-centred approaches to troubleshooting. Regulated online communities and improved access to manufacturer support are also essential. Addressing social inequalities in repair access is crucial, requiring collaborative efforts across disciplines. Our findings contribute to informed policy discussions and industry practices, aiming to foster sustainable and user-centric repair solutions in the evolving landscape of IoT technology.

Acknowledgments. This work is supported by the Engineering and Physical Sciences Research Council funded project **Fixing the Future: The Right to Repair and Equal-IoT [EP/W024780/1].**

References

[1] Ahmed, S.I., Guha, S., Rifat, Md.R., Shezan, F.H., and Dell, N. Privacy in repair. Proceedings of the Eighth International Conference on Information and Communication Technologies and Development, (2016).

[2] Boniface, C., Urquhart, L., and Terras, M. Towards a right to repair for the internet of things: A review of legal and policy aspects. Computer Law &; Security Review 52, (2024), 105934.

[3] Conway, L. Research briefing right to repair regulations. researchbriefings, 2021. https://researchbriefings.files.parliament.uk/documents/CBP-9302/CBP-9302.pdf.

[4] Cooper, T., & Salvia, G. Fix it: barriers to repair and opportunities for change (2018).

[5] DiSalvo, C., Sengers, P., and Brynjarsdóttir, H. Mapping the landscape of sustainable HCI. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, (2010).

[6] EU. Report on the proposal for a directive of the European Parliament and of the council on common rules promoting the repair of goods and amending regulation (EU) 2017/2394, Directives (EU) 2019/771 and (EU) 2020/1828: A9-0316/2023: European Parliament. REPORT on the proposal for a directive of the European Parliament and of the Council on common rules promoting the repair of goods and amending Regulation (EU) 2017/2394, Directives (EU) 2019/771 and (EU) 2020/1828 | A9-0316/2023 | European Parliament, 2023. https://www.europarl.europa.eu/doceo/document/A-9-2023-0316_EN.html.

[7] Forti, V., Balde, C. P., Kuehr, R., & Bel, G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential (2020).

[8] Hansson, L.Å., Cerratto Pargman, T., and Pargman, D.S. A decade of sustainable HCI. Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, (2021).

[9] Haque, S.M., Haque, M.R., Nandy, S., et al. Privacy vulnerabilities in Public Digital Sevice Centers in Dhaka, Bangladesh. Proceedings of the 2020 International Conference on Information and Communication Technologies and Development, (2020).

[10] Koebler, J. Tim Cook to investors: People bought fewer new iphones because they repaired their old ones. VICE, 2019. https://www.vice.com/en/article/zmd9a5/tim-cook-to-investors-people-bought-fewer-new-iphones-becausethey-repaired-their-old-ones.

[11] Lefebvre, M. To repair or not to repair: An investigation of the factors influencing prosumer repair propensity, 2019.

[12] Lovejoy, B. British right to repair law comes into force today but excludes smartphones and computers. 5 Mac, 2021. https://9to5mac.com/2021/07/01/british-right-to-repair-law/.

[13] Mankoff, J.C., Blevis, E., Borning, A., et al. Environmental sustainability and interaction. CHI '07 Extended Abstracts on Human Factors in Computing Systems, (2007).

[14] van Nes, N. and Cramer, J. Influencing product lifetime through product design. Business Strategy and the Environment 14, 5 (2005), 286–299.

[15] Pérez-Belis, V., Braulio-Gonzalo, M., Juan, P., and Bovea, M.D. Consumer attitude towards the repair and the second-hand purchase of small household electrical and electronic equipment. A Spanish case study. Journal of Cleaner Production 158, (2017), 261–275.

[16] Perzanowski, A. The right to repair, (2021).

[17] Rafi, S., Dia, R.R., Gazi, M.A., and Islam, Q. Fairphone: The phone that protects the planet, (2024).

[18] Remy, C., Bates, O., Dix, A., et al. Evaluation beyond usability. Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, (2018).

[19] Roskladka, N., Jaegler, A., and Miragliotta, G. From "right to repair" to "willingness to repair": Exploring consumer's perspective to product lifecycle extension. Journal of Cleaner Production 432, (2023), 139705.

[20] Russell, J.D., Svensson-Hoglund, S., Richter, J.L., Dalhammar, C., and Milios, L. A matter of timing: System requirements for repair and their temporal dimensions. Journal of Industrial Ecology 27, 3 (2022), 845–855.

[21] Singh, N. and Ogunseitan, O.A. Disentangling the worldwide web of e-waste and climate change co-benefits Circular Economy 1, 2 (2022), 100011.

[22] Sonego, M., Echeveste, M.E., and Debarba, H.G. Repair of electronic products: Consumer Practices and Institutional Initiatives. Sustainable Production and Consumption 30, (2022), 556–565.

[23] Stead, M., Coulton, P., Pilling, F., Gradinar, A., Pilling, M., and Forrester, I. More-than-human-data interaction. Proceedings of the 25th International Academic Mindtrek Conference, (2022).

[24] Svensson, S., Richter, J.L., Maitre-Ekern, E., Pihlajarinne, T., Maigret, A., and Dalhammar, C. The emerging 'right to repair' legislation in the EU and the U ... - lu, 2018. https://lucris.lub.lu.se/ws/portalfiles/portal/63585584/Svensson_et_al._Going_Green_CARE_INNOVATION_2018_PREP RINT.pdf.

[25] Svensson-Hoglund, S., Richter, J.L., Maitre-Ekern, E., Russell, J.D., Pihlajarinne, T., and Dalhammar, C. Barriers, enablers and market governance: A review of the policy landscape for repair of consumer electronics in the EU and the U.S. Journal of Cleaner Production 288, (2021), 125488.