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Is This the End? - Lifetime of Electrical and Electronic Equipment

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Abstract: The rapid advancement of technology, coupled with global digitalisation and the growing demand for innovative consumer electronics, has led to a dramatic increase in the production and consumption of electrical and electronic equipment (EEE). This trend has raised significant concerns regarding the sustainability of EEE usage, particularly in terms of their obsolescence, disposal, and environmental impact. Addressing these concerns, this study surveyed 600 undergraduate students, who reported on 14 different types of EEE, to explore the reasons for obsolescence (RQ1), the most common methods of managing obsolete devices based on their types (RQ2), and students' awareness of alternative waste management methods (RQ3). Results were reported using frequencies and percentages. Findings reveal that obsolescence is mainly driven by "broken beyond repair," "worn-out technology," "outdated technology," and "lack of required functions," indicating that absolute and technical obsolescence are the primary factors. The most common way of dealing with obsolete devices is to "keep it" across all device types, with "throwing away" emerging as another frequent method for electrical devices. More than half of the students are aware of accessible alternatives, such as "online sales" and "charity donations," though irregular or infrequent options tend to have lower awareness levels. This study highlights the behavioural trends and gaps in awareness among students regarding EEE obsolescence and disposal, emphasising the importance of promoting sustainable practices and raising awareness about accessible waste management alternatives.

Introduction

The rapid advancement of technology and global digitalisation has led to a significant increase in the use of electrical and electronic equipment (EEE). While the diversity of electronic devices and their widespread use have brought numerous benefits and conveniences, it has also given rise to a pressing issue: e-waste. The European Commission defines Waste Electrical and Electronic Equipment (WEEE) as one of the fastest-growing waste types in the world (Romagnoli et al., 2022). Industrialisation, urbanisation, and higher disposable income are the primary triggers of the EEE industry and e-waste (Forti et al., 2020). Moreover, higher consumption rates, short life cycles of EEE, and limited repair alternatives for broken EEE are some facilitators of e-waste generation, as illustrated in Figure 1 (Forti et al., 2020).

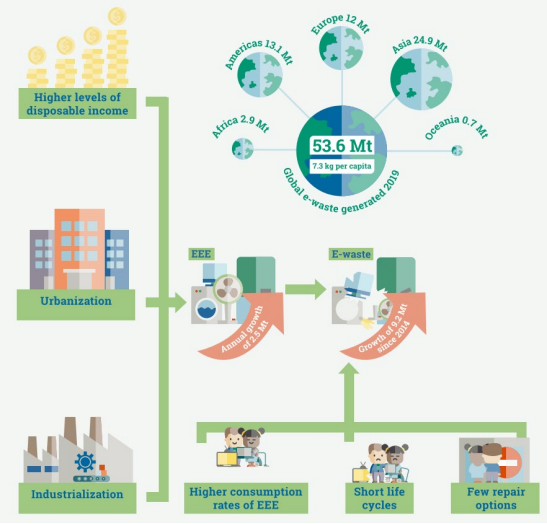

Figure 1. Overview of e-waste. © Forti et al., 2020.

Macleod, categorises the product life cycle as a holistic experience in three phases: on-boarding, usage and off-boarding, and emphasises that off-boarding is the most neglected phase of the service/product lifecycle (Macleod, 2017). This shows that most industry stakeholders reduce their engagement during the off-boarding phase. Users can become confused about the action they are supposed to

take when a product does not work as promised in advertisements or within the user manual.

This study draws on the findings of an online survey of 600 UK undergraduate students to investigate the reasons for obsolescence in electrical and electronic devices (research question 1 -RQ1-) with an aim to identify the most common methods of dealing with obsolete devices based on their types (research question 2 -RQ2-). Additionally, it explores the awareness levels of undergraduate students regarding alternative ways to manage electronic waste (research question 3 -RQ3-).

Obsolescence

Obsolescence is defined under varying categories in the literature. For example, van Nes et al. (1999), in their pioneering study systematically defined six obsolescence categories: technical, economic, ecological, aesthetic, feature and psychological obsolescence. In addition, Cooper (2004) defined absolute obsolescence as "needs to be distinguished from that arising from product failure". Cooper (2004) also explains obsolescence under three categories: psychological, economic, and technological and mentions absolute obsolescence.
Moreover, (Burns, 2016) drew attention to societal obsolescence by considering the impact of social norms on human behaviour. They also mention technological obsolescence is the most consistently occurring type of obsolescence due to rapid technological developments (Burns, 2016). More recently, Wilson et al. (2017) categorised obsolescence as absolute, functional, aesthetic, economic, technological, ecological, psychological, and societal by synthesising the existing literature (summarised above) according to their comprehensive literature review in their study focusing on hibernating mobile phones.

Alternative scenarios for end-of-lifetime of EEE

Vezzoli (2018) defines product life cycle processes with the following stages: pre-production, production, distribution, use, and disposal. King et al., (2006) explain that consideration of whole lifecycle from raw materials to final disposal is a way to achieve a closed loop design. They have created a timeline from new material to waste material and defined the stages as processing, assembly and sell and use.

Vezzoli (2018) also creates a product-system life cycle with a systemic approach by including chemical and physical inputs and outputs. Various user related terms, such as reuse and recycle, can be seen in this figuration even if it is not indicated in that way. It is important to evaluate product life cycle by considering user behaviour as it has a significant potential to extend product lifetime and reshape end of lifetime scenarios.

Methodology

Undergraduate students at Loughborough University's Loughborough campus were selected for purposive sampling for the study. The questionnaire was circulated online, and 600 responses were received between October and November 2023.
The devices included in the scope of the study are listed in Figure 2, along with their pictograms. The pictograms are introduced here to prevent confusion when used in data visualisations in the figures of the results section. In addition to the mentioned devices, an option for "other" was also included to determine whether there is a type of device common in the sampling group but not covered in the scope of the study.

Figure 2: Devices included in the scope with related pictograms

Questions were created that asked about current devices, obsolete devices, obsolescence reasons, and awareness of alternative ways to get rid of obsolete devices using a multiple selection format. Questions about actions taken with obsolete devices were in a multiple-choice format. The investigation of obsolescence reasons and actions taken with obsolete devices were repeated for each selected obsolete device. Thus, it was possible to get results for all devices separately.

Questions regarding obsolescence reasons and associated actions taken with obsolete devices were adapted from Wilson et al., (2017). Some obsolescence reasons from their study were excluded or altered to tailor choices to the scope of this study, as their study only focused on mobile phones.
Initially, the clarity of the questionnaire was tested with four participants, and later further clarified with two additional participants, to ensure comprehension.
The participant profiles, current and obsolete devices were reported using frequencies and percentages, providing insights into ownership and obsolescence trends. Obsolescence reasons and actions taken with obsolete devices were summarised similarly. Low-response reasons were deemed insignificant, while the most frequent reasons (higher than 30%) were highlighted for enhanced data visualisation using figures.
Line graphs were created to illustrate patterns of awareness for alternative ways to deal with e-waste, whilst further enhancing the understanding of e-waste disposal behaviours among participants.

Results

The majority of respondents (more than 80%) consisted of home students. This aligns with the ratio of home to international students at Loughborough University as stated in their statistics (Loughborough University, 2023). As such, the results of this study can be reliably utilised to represent the undergraduate student population at Loughborough University. 600 respondents reported 4,444 devices they currently own and use, corresponding to an average of 7.4 devices per person.
Table 1 provides insights into the current ownership and obsolescence rates of various electronic devices, establishing their ownership frequency and usage patterns. Mobile phones are the most prevalent among the listed devices, with 600 responses indicating current ownership. However, a significant portion of respondents (459) have at least one obsolete mobile phone. This data might refer to respondents' rapid turnover or replacement cycle for mobile phones while considering the age range of undergraduate students. Respondents specified devices, such as Bluetooth speakers, cameras, and battery chargers under the “other” option, but the response frequencies were not high enough to include them within the analysis.

Device	Current	Obsolete
Mobile phone	600	459
Headphone	593	308
Laptop / MacBook	579	293
Screen / TV	344	92
Tablets	331	226
Electric toothbrush	331	122
Hair styling appliance	321	86
Game console	270	168
Smartwatch	256	86
Personal grooming devices	224	56
Smart speaker	221	47
Desktop computer	154	63
Electrical beauty devices	102	23
E-book reader	101	69
Other	17	9

Table 1. Number of participants with current and obsolete devices.

Obsolescence Reasons

'Broken beyond repair' was the most frequently selected reason for the obsolescence of wearable electronic devices, with 30% of smartwatches and 57% of headphones. This trend was also observed in the results for hair styling appliances (49%), electric toothbrushes (41%), electrical beauty devices (35%)’ and personal grooming devices (33%) (Figure 3).

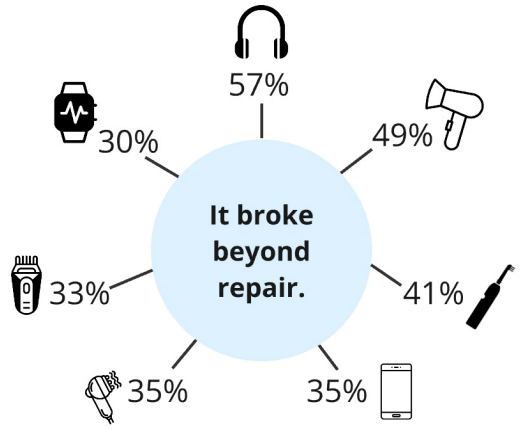

Figure 3. Obsolescence reason: It broke beyond repair.

Technological wear was cited as a reason for obsolescence for 55% of mobile phones, 52% of laptops, and 47% of tablets (Figure 4).

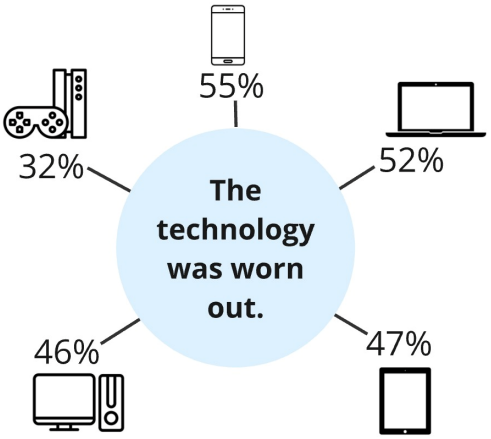

Figure 4. Obsolescence reason: The technology was worn out.

Outdated technology was identified as a factor for 50% of mobile phones, 45% of laptops, and 40% of tablets (Figure 5).

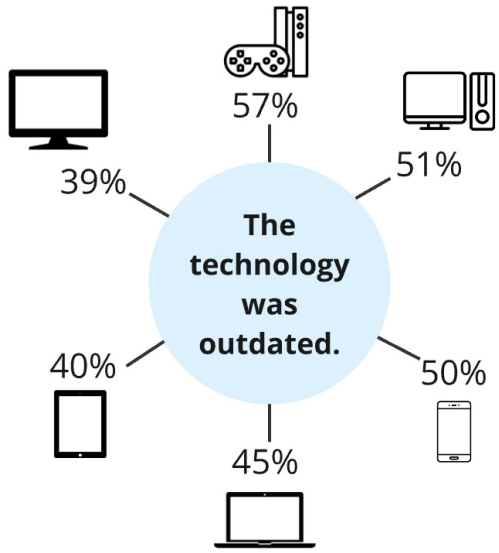

Figure 5. Obsolescence reason: The technology was outdated.

"It no longer had the specific function I required" was another popular answer for laptops, smart speakers and e-book readers, with more than 30% of responses (Figure 6).

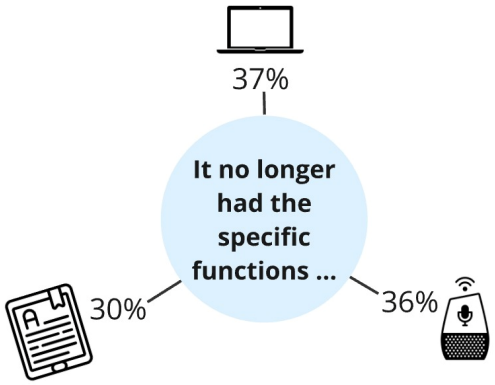

Figure 6. Obsolescence reason: It no longer had the specific functions I required.

Actions Taken with Obsolete Devices

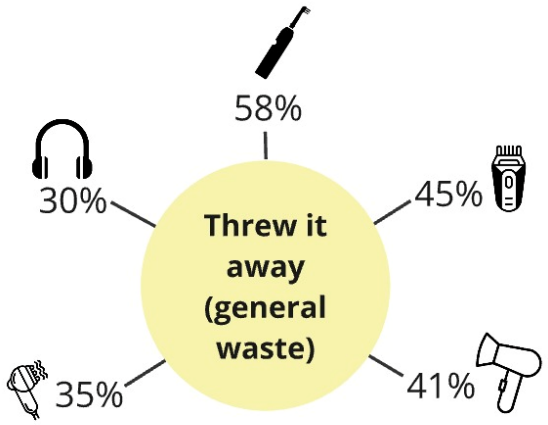

Figure 7. Actions taken: Threw away.

According to the responses, the most common way to deal with obsolete electronic devices (mobile phones, laptops, tablets, e-book readers, desktop computers, screens/TVs, game consoles, smartwatches, smart speakers, headphones) appeared to be keeping hold of them, whilst, for electrical devices (hair styling appliances, electric toothbrushes, personal grooming devices and electrical beauty devices), it seemed that throwing them away was a more common route for disposal (Figure 7, Figure 8).

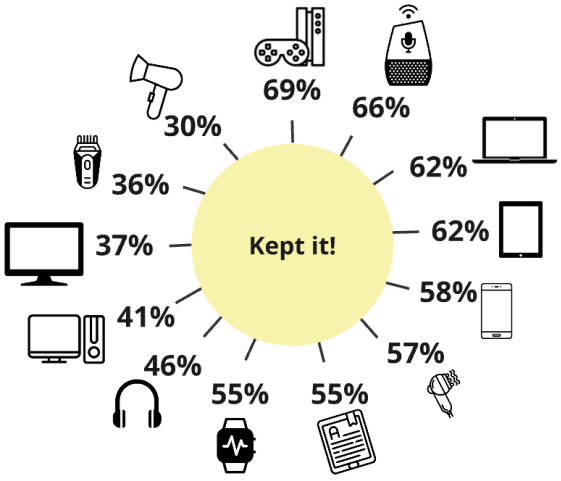

Figure 8. Actions taken: Kept it.

Awareness of Current Alternatives

Alternative ways to deal with an obsolete electrical or electronic device were listed by considering the living area of the sample group. In addition to all common alternatives, Give n Go is an alternative offered by the university that allows on-campus resident students to get rid of their electrical and electronic devices at the end of semesters. All alternative ways were captured in the questionnaire by adding an option for "other". Respondents were asked to select "none" if they were unaware of any alternatives. The number of students that selected an alternative is listed in Figure 9.

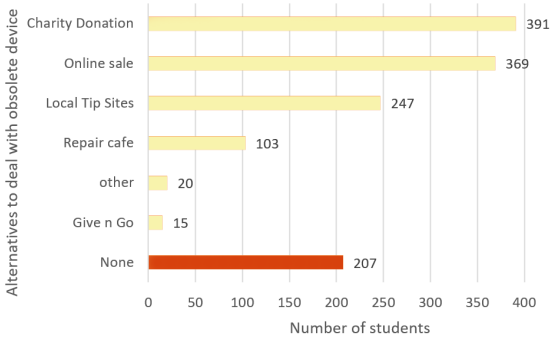

Figure 9. Awareness of alternative ways to deal with obsolete devices.

Even if charity donations and online sales were acknowledged by more than half of the respondents, when they were asked about their actions taken with obsolete devices, it was identified that these alternative ways were not utilised for their own obsolete devices.

Discussion

Most of the research investigating e-waste focuses on general awareness (Adanu et al., 2020; Miner et al., 2020; Mor et al., 2021) or just a single electronic device, specifically mobile phones (Huang & Truong, 2008; Jang & Kim, 2010; Ongondo & Williams, 2011; Wilson et al., 2017; Ylä-Mella et al., 2015). Apart from mobile phones, there is a noticeable gap in the literature regarding the understanding of users' behaviour, especially within device-specific research.

Absolute obsolescence refers to a product's physical failure (Cooper, 2004) which has been integrated in the related question's choices as "It broke beyond repair" and "The technology is worn out". These two appear as the most common reasons for obsolescence.

"The technology was outdated." represented technological obsolescence as inferior to newer products in a way that affected the results (Burns, 2016; Van Nes et al., 1999).

Lastly, the lack of specific functions means that the product is incapable of fulfilling the user's functional requirements, which is referred to as functional obsolescence by Cooper (2004).

Actions taken with obsolete devices have been illustrated with related sustainability terms on Table 2.

	Related terms
Kept it	Hibernation, repurpose
Recycled it	Recycle
Traded it in for a new one.	Repair, Refurbish
N/A	N/A
Gifted it	Reuse, Repurpose
Threw it away (general waste)	N/A
Gave it to a charity	Repair, Reuse
Sold it on Marketplace or another second-hand selling platform/app	Reuse, Repair
Other	N/A

Table 2. Actions taken with obsolete devices and related terms.

Various possible actions were given as an option in the multiple-choice question for each obsolete device. All possible actions were evaluated based on their association with life cycle assessment alternatives.
"Kept it" meant that the device is no longer used for its primary purpose; it is in hibernation or in use for a small task (e.g. using an old phone as an alarm clock).
"Gifted it", in the context of this questionnaire, meant that the mentioned device was given to someone with no financial return to keep the device in use and fulfil someone else's needs.
"Gave it to a charity" represents giving an obsolete electronic device to a charity. This option was considered in two ways: the charity gives the electronic device to someone who needs it, or the charity facilitates the repair/recycling of the electronic device (Guo & Xu, 2021).
Kiddee et al. (2013) explained the health and environmental risks of recycling and disposal of electronic devices by referencing studies on the levels of hazardous substances exposed to people living near areas where e-waste is recycled. Accordingly, giving obsolete devices to a charity can be categorised as related to recycling and partly related to environmental risk. Similarly, "recycled it" is related to recycling and partly to environmental risk. Additionally, in the case of giving the electronic device to someone who needs it, it is categorised as partly related to reuse.
"Threw it away" was evaluated as the most environmentally damaging way to deal with obsolete devices because of their high potential to pollute the environment (Kiddee et al., 2013). While considering the perspectives of various companies, “trade in”, in the context of this questionnaire, was seen to consist of two potential processes: repairing (refurbishing) or recycling (Curvelo Santana et al., 2021). For this reason, "Traded it in for a new one" was related to repairing and refurbishing the device. The finding regarding students’ awareness of alternatives to deal with e-waste points to potential gaps in students’ knowledge or their accessibility to e-waste options that could be addressed through targeted awareness campaigns, but this required further investigation for justification.

All the terms mentioned above from the literature related to actions taken with obsolete devices were illustrated with actions and the product life cycle process (Figure 10). Product life cycle terms were adapted from Vezzoli, (2018) and illustrated in grey rectangles, related terms were written in white rectangles and actions taken with obsolete devices visualised in green circles.

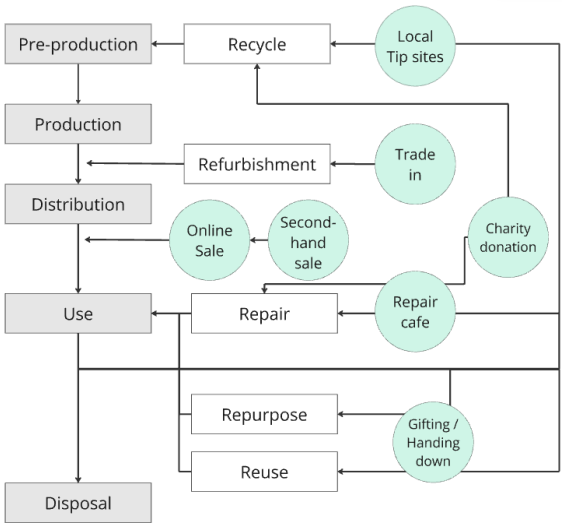

Figure 10. Initial model of user actions affecting product life cycle.

Conclusions

This study provided answers to the three research questions defined in the introduction.
RQ1: The most common reasons for obsolescence are broken beyond repair, worn-out technology (incapable of running the main required functions), outdated technology (has fallen behind the latest technology), and lack of function that the user requires. It shows that

absolute and technical obsolescence are the main reasons why people stop using electrical and electronic devices.
RQ2: This study found the most common methods of dealing with obsolete devices based on their types as “kept it” for all types of devices, but for electrical devices (including headphones), throwing away is another common alternative.
RQ3: The study determined that more than half of the students are aware of alternative ways, which are available at any time, to deal with obsolete electrical and electronic devices, even if they are not preferred, such as online sales and charity donations. On the other hand, irregular or non-frequent alternatives, such as repair cafés or “give n go” currently are not desirable alternatives. This shows that accessibility and frequency are variables that affect awareness of alternative ways to deal with obsolete electrical and electronic devices.

Further studies

A literature-based approach could examine the environmental impact of different disposal actions to understand the relative sustainability of various choices better. Additionally, follow-up studies could investigate the motivations and barriers that influence students' decisions to keep or dispose of their obsolete devices, and potential drivers that could encourage more sustainable actions. There is also an opportunity to investigate students' perceptions of responsibility for e-waste and to explore why some disposal options, like repair cafés or campus Give 'n' Go initiatives, remain underutilised. Understanding these behaviours and perspectives in greater detail will support the development of strategies that encourage more environmentally responsible e-waste management practices among the student population.

Acknowledgments

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Appendix I

Obsolescence reasons for devices

	Mobile phone	Laptop / MacBook	Tablets	E-book reader	Desktop computer	Screen / TV	Game console	Smartwatch	Headphones	Smart speaker	Hair styling appliance	Electric toothbrush	Personal grooming devices	Electrical beauty devices	Other
al respondent	459	293	226	69	63	92	168	86	308	47	86	122	56	23	9
It broke beyond repair.	**161 (35.1%)**	83 (28.3%)	59 (26.1%)	11 (15.9%)	11 (17.5%)	23 (25%)	8 (4.8%)	**26 (30.2%)**	**175 (56.8%)**	6 (12.8%)	**42 (48.8%)**	**50 (41%)**	**40 (32.8%)**	**8 (34.8%)**	1 (11.1%)
The technology was worn out.	**252 (54.9%)**	**153 (52.2%)**	**105 (46.5%)**	12 17.4%)	**29 (46%)**	18 (19.6%)	**54 (32.1%)**	17 (19.8%)	69 (22.4%)	10 (21.3%)	16 (18.6%)	27 (22.1%)	18 (14.8%)	5 (21.7%)	1 (11.1%)
It no longer had the specific functions that I required.	97 (21.1%)	**107 (36.5%)**	64 (28.3%)	**21 (30.4%)**	16 (25.4%)	23 (25%)	43 (25.6%)	21 (24.4%)	47 (15.3%)	**17 (36.2%)**	17 (19.8%)	11 (9%)	14 (11.5%)	6 (26.1%)	0
It was no longer clean, shiny, or new.	23 (5%)	12 (4.1%)	7 (3.1%)	1 (1.4%)	0	7 (7.6%)	6 (3.6%)	3 (3.5%)	11 (3.6%)	1 (2.1%)	4 (4.7%)	16 (13.1%)	5 (4.1%)	1 (4.3%)	0
It was no longer novel, stylish or prestigious.	24 (5.2%)	4 (1.4%)	4 (1.8%)	0	2 (3.2%)	3 (3.3%)	10 (6%)	4 (4.7%)	14 (4.5%)	3 (6.4%)	0	2 (1.6%)	3 (2.5%)	1 (4.3%)	0
It cost too much money to repair (if broken).	71 (15.5%)	34 (11.6%)	21 (9.3%)	0	5 (7.9%)	2 (2.2%)	4 (2.4%)	8 (9.3%)	25 (8.1%)	3 (6.4%)	2 (2.3%)	2 (1.6%)	1 (0.8%)	0	0
The technology was outdated.	**228 (49.7%)**	**132 (45.1%)**	**91 (40.3%)**	20 (29%)	**32 (50.8%)**	**36 (39.1%)**	**95 (56.5%)**	18 (20.9%)	78 (25.3%)	8 (17%)	14 (16.3%)	7 (5.7%)	8 (6.6%)	2 (8.7%)	1 (11.1%)
It was bad for the environment.	1 (0.2%)	0	0	0	2 (3.2%)	2 (2.2%)	1 (0.6%)	0	0	0	2 (2.3%)	3 (2.5%)	1 (0.8%)	0	0
I am more emotionally attached to the replacement.	7 (1.5%)	7 (2.4%)	5 (2.2%)	5 (7.2%)	2 (3.2%)	2 (2.2%)	14 (8.3%)	3 (3.5%)	23 (7.5%)	2 (4.3%)	2 (2.3%)	3 (2.5%)	3 (2.5%)	0	1 (11.1%)
It was no longer socially acceptable to use	15 (3.3%)	2 (0.7)	1 (0.4%)	1 (1.4%)	1 (1.6%)	0	17 (10.1%)	1 (1.2%)	4 (1.3%)	1 (2.1%)	0	0	2 (1.6%)	0	0
er	24 (5.2%)	10 (3.4%)	26 (11.5%)	11 (15.9%)	4 (6.3%)	6 (6.5%)	22 (13.1%)	15 (17.4%)	16 (5.2%)	7 (14.9%)	5 (5.8%)	19 (15.6%)	35 (28.7%)	1 (4.3%)	**5 (55.6%)**

Appendix II

Actions taken with obsolete devices

	Total respondent	Kept it	Gifted it	Gave it to a charity	Recycled it	Trew it away (general waste)	Traded it in for a new one.	Sold it on Marketplace or another second-hand selling platform/app	Other
Mobile phone	459	**267 (58.2%)**	56 (12.2%)	0	28 (6.1%)	11 (2.4%)	55 (12%)	40 (8.7%)	2 (0.4%)
Laptop / MacBook	293	**182 (62.1%)**	46 (15.7%)	26 (8.9%)	13 (4.4%)	12 (4.1%)	10 (3.4%)	3 (1%)	1 (0.3%)
Tablets	226	**141 (62.4%)**	20 (8.8%)	3 (1.3%)	21 (9.3%)	14 (6.2%)	8 (3.5%)	14 (6.2%)	5 (2.2%)
E-book reader	69	**38 (55.1%)**	11 (15.9%)	1 (1.4%)	9 (13%)	8 (11.6%)	0	1 (1.4%)	1 (1.4%)
Desktop computer	63	**26 (41.3%)**	6 (9.5%)	5 (7.9%)	13 (20.6%)	6 (9.5%)	2 (3.2%)	3 (4.8%)	2 (3.2%)
Screen / TV	92	**34 (37%)**	10 (10.9%)	4 (4.3%)	14 (15.2%)	15 (16.3%)	2 (2.2%)	11 (12%)	2 (2.2%)
Game console	168	**115 (68.5%)**	15 (8.9%)	10 (6%)	3 (1.8%)	2 (1.2%)	3 (1.8%)	18 (10.7%)	2 (1.2%)
Smartwatch	86	**47 (54.7%)**	7 (8.1%)	1 (1.2%)	9 (10.5%)	9 (10.5%)	3 (3.5%)	8 (9.3%)	2 (2.3%)
Headphone	308	**141 (45.8%)**	24 (7.8%)	2 (0.6%)	29 (9.4%)	**91 (29.5%)**	6 (1.9%)	4 (1.3%)	11 (3.6%)
Smart speaker	47	**31 (66%)**	8 (17%)	0	3 (6.4%)	3 (6.4%)	1 (2.1%)	1 (2.1%)	0
Hair styling appliance	86	**26 (30.2%)**	8 (9.3%)	1 (1.2%)	13 (15.1%)	**35 (40.7%)**	1 (1.2%)	1 (1.2%)	1 (1.2%)
Electric toothbrush	122	34 (27.9%)	0	0	16 (13.1%)	**71 (58.2%)**	1 (0.8%)	0	0
Personal grooming devices	56	**20 (35.7%)**	1 (1.8%)	0	9 (16.1%)	**25 (44.6%)**	0	0	1 (1.8%)
Electrical beauty devices	23	**13 (56.5%)**	0	0	0	**8 (34.8%)**	0	1 (4.3%)	1 (4.3%)
Other	9	**4 (44.4%)**	1 (11.1%)	0	1 (11.1%)	1 (11.1%)	0	1 (11.1%)	1 (11.1%)