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UNLOCKING THE VALUE OF STOCKPILED MOBILE HANDSETS: A DELPHI EVALUATION OF FACTORS INFLUENCING END OF USE

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ABSTRACT

Meeting consumers' demands for electrical and electronic equipment (EEE) products in the face of diminishing natural resources necessitates a shift from take-make-dispose to circular economy approaches. Mobile handsets are ubiquitous but only a fraction are returned into the economy at the end; many are locked in consumers' households. These small EEE hold residual value as well as critical resources, such as Rare Earth Elements. Incentives for destockpiling exist but are insufficient to alter long-term end-of-use behaviour. Household recycling behaviour tends to be used as a template for EEE end-of-use. But established explanatory factors for household recycling might not be fully relevant for small electronic devices: their size permits stockpiling, whilst their continued utility can encourage retention as back-up or "safety" devices. This study aimed to elucidate the relevance of factors specific to the nature of small EEE, notably their physical characteristics and working order. A panel of academics and professionals from the global waste and resource management sector was consulted using Delphi methods. The results show that factors commonly applied to foster recycling, such as altruism or pro-environmental behaviour, do not necessarily apply to small EEE. On the other hand, the device's features and working order are critical factors in the end-of-use decision-making process. This study concludes that practical and situational factors should be used to favourably alter decisions for small EEE, including devices' characteristics. In effect, updated situational factors could unlock a global "destockpile lifestyle" to realise full value from the reuse and recycling of small EEE.

1. INTRODUCTION

Global demand for and ownership of electric and electronic products are at unprecedented levels. The COVID-19 pandemic has generated further demand due to requirements for home working and schooling. In 2020, more than 50 million tonnes of such products were placed on the global market (UNEP, 2021). Since 2014 there have been more mobile and smart phones than humans on earth (The Independent, 2014); more than 2 billion mobile/smart phones were shipped in 2020 (IDC, 2021). The ubiquitous distribution of mobile phone handsets contributes to high ownership levels: in 2010, 99% of the 2.4 million students in the United Kingdom (UK) owned at least one mobile handset and average ownership was 1.5 per individual (Ongondo & Williams, 2011a). The replacement of mobile handsets is rapid. Students in higher education, for example, typically replace their mobile handsets within three years of purchase (Ongondo & Williams, 2011b), at which point functionality is often still usually retained.

High levels of ownership and relatively short periods of use lead to the generation of high volumes of end-of-use and end-of-life electrical and electronic equipment (EEE), particularly for mobile handsets. Globally, the production of waste EEE ("e-waste" or "WEEE") is predicted to reach 120 million tonnes by 2050 (UNEP, 2021); WEEE is considered the fastest growing solid waste sector (Oswald & Reller, 2011). The global situation is driven by actions at a discrete scale: when an individual no longer needs or wants an item of EEE such as a mobile handset, there are different potential fates with contrasting impacts and challenges.

In broad terms, an end-of-use or end-of-life mobile handset could be (1) disposed of as waste; (2) recycled as a means to recover materials for the manufacture of new goods, (3) sold or given to another owner and reused; or (4) retained by the owner but no longer used. The fate of such products is related to their physical condition and functionality. In the context of this study, we use the term WEEE to identify end-of-life mobile handsets as opposed to "used EEE" (UEEE) which identifies end-of-use mobile handsets.

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For all end-of-use and end-of-life mobile handsets, disposal severely restricts the potential for beneficial outcomes. Potentially recoverable materials within WEEE and UEEE products that are destined for landfill or incineration are lost, failing to re-enter the manufacturing loop, and thereby failing to produce financial or material value (Ongondo & Williams, 2012). The metals, plastics, fire retardants and other contaminants contained within WEEE and UEEE (Bonifazi et al., 2021; Hennebert, 2020) can cause environmental contamination when disposed of to landfill or incinerated (Barba-Gutiérrez et al., 2008). There is scope for considerable improvement in this regard; in 2010 more than 130 million mobile phones were discarded in the US (Electronic Takeback, 2016). In the UK alone, there are 40 million unused electronic devices in working condition (Royal Society of Chemistry, 2019). These millions of unused, and often in working condition devices, represent untapped value. Either in lost opportunities to resell a device in working condition on the secondary market or to recycle unworking devices to harness critical materials such as rare earth elements (Omodara et al., 2019).

Items that are beyond viable repair, in either technical or economic terms, will not have the potential for reuse: mobile handsets of this ilk would be considered end-of-life, i.e. WEEE or e-waste. In this case, the aims and principles of the waste hierarchy (Directive 2008/98/EC) and circular economy (Ellen MacArthur Foundation, 2013) infer that recycling would be preferred to disposal. Achievements in this respect appear poor (Stegmann, 2021). For developed economies, it has been estimated that typically only 10-20% of mobile/smart phones are recycled (Ellen MacArthur Foundation, 2013; US EPA, 2014; Green Alliance, 2015). Small WEEE items (smaller than 25 cm^3; EC Directive 2012/19/EU) are considered one of the least recycled WEEE categories (Bartl et al., 2018; Ellen MacArthur Foundation, 2013). There is potential for recycled mobile handsets to provide large quantities of valuable materials (e.g. Rare Earth Elements [REE]); to achieve this, a high number of discarded devices, each containing small quantities of REE, would have to be collected and the materials therein recovered (Oswald & Reller, 2011; UNEP, 2011; Alamgir et al., 2012). There is obvious merit in increasing efforts to improve WEEE collection rates and recycling technologies, e.g. for REE (Toyota, 2014). At the same time, poorly regulated facilities and processes for recycling WEEE present risks to human health and can lead to environmental contamination (Robinson, 2009; Milovantseva & Saphores, 2013; Awasthi et al., 2018).

Mobile handsets that retain functionality should be considered end-of-use (UEEE) as opposed to end-of-life (WEEE). For UEEE, reuse would be the preferred fate (Directive 2008/98/EC; Ellen MacArthur Foundation, 2013). Recycling mobile handsets that retain utility fails to make full use of the energy and materials used in their production, packaging and delivery to the point of sale, and could be considered premature. Opportunities for reuse include direct sale to individuals or commercial businesses, and donation to individuals or charitable organisations; the latter option is prevalent in the UK but not generally elsewhere.

Retention of UEEE or WEEE by the current owner without continued use is also suboptimal: the ongoing utility of UEEE remains dormant, as do the potentially recoverable materials within WEEE. Storage of end-of-use or end-of-life mobile handsets is facilitated by their relatively small size; several devices may be stored with negligible impact on space within the owner's dwelling. Storage of devices retains resources in hibernation, resulting in continued demand for virgin raw materials for the production of new devices, and associated impacts. Storage appears common and widespread: a decade ago, an estimated 3.7 million mobile handsets were stockpiled by students in higher education in the UK (Ongondo & Williams, 2011b) and an estimated 50-90 million devices have been stockpiled globally (Silveira & Chang, 2010). Indeed, Shittu et al. (2021) reported that 97% of EEE collected from a distinct urban mine in a recent trial was reusable and subsequently donated to charities for sale and reuse.

Environmental, health and resource consequences of UEEE and WEEE are intrinsically linked to consumers' behaviour. The stockpiling or disposal of mobile handsets, in particular, is a lost opportunity for recycling or reuse. The evident loss of mobile handsets to disposal and failure to recirculate stored devices through reuse or recycling suggests that existing models and frameworks intended to support collection systems merit improvement. In this context, improved understanding of those factors influencing consumers' end-of-use or end-of-life behaviour concerning mobile handsets could inform and guide the design of collection systems and incentives, and thereby contribute to the achievement of higher collection rates of WEEE and UEEE, and associated environmental, economic and social benefits.

2. MOTIVATORS OF CONSUMERS' BEHAVIOUR IN RELATION TO WEEE AND UEEE

To consider the potential for improving understanding of those factors influencing consumers' end-of-use or end-of-life behaviour, it is instructive to review received wisdom with regard to motivators of consumers' more general behaviour in the context of waste and resources. Differentiation of influencing factors into "intrinsic" (personal factors) and "extrinsic" (situational factors) (Schultz et al., 1995) provides a framework that provides background and insight to direct efforts for enhancement of end-of-life and end-of-use mobile handset collection.

2.1 Extrinsic motivators and monetary incentives

Extrinsic motivators are illustrated by monetary incentives in the form of either financial penalties (e.g. taxes) or rewards. Willingness-to-pay (WTP) and pay-as-you-throw (PAYT) studies have demonstrated the difficulties in associating monetary incentives with "waste" (Afroz et al., 2013; Le Bozec, 2008; Song et al., 2012; Xu et al., 2018). Given the often low monetary value of residual materials, financial incentives are necessarily low and taxes are unpopular by definition. Other studies, mainly in the United States, have investigated consumers' willingness to pay Advanced Recycling Fees (ARF) to finance WEEE collection schemes and develop subsidies to incentivise consumers. Nixon and Saphores (2007), for example, found that consumers were willing to pay 1% of the item's retail price on average but this amount is insufficient to create a sustainable collection scheme. Taiwan has attempted to tackle the issue of market-based incentives for packaging containers, which have very little intrinsic monetary value attached to them (Bor et al., 2004). With a complex system of ARF associated with the involvement of local government and subsidies, Bor et al. (2004) suggest developing a specific market for these containers, by creating new rules to influence the behaviour of producers, consumers, and local government. Whilst the ARF approach is laudable, the actual implementation remains to be demonstrated. There are also differences between developed and developing countries regarding intentions and behaviour towards WEEE (Shahrasbi et al., 2021). Consumers in developed economies are more in favour of monetary incentives. Whereas consumers in developed economies feel stronger towards intrinsic incentives related to environmental and social aspects.

Jones et al. (2010) investigated social factors influencing perceptions of willingness to pay based on social capital for household waste (i.e. social trust, institutional trust, social networks, compliance with social norms); participants in this study were willing to pay ca. €0.5 for each waste bag. Specifically for WEEE, a survey in China estimated that 52% of respondents refused to cover a fraction of recycling costs and ⅔ of those respondents willing to pay were prepared to pay up to 5% of the recycling costs (Yin et al., 2013). The higher the monthly income, the more likely respondents were willing to pay; 35% of respondents wanted to pay at the time of purchase, either explicitly as an advanced recycling fee or simply embedded or hidden in the product price; only 11% were willing to pay this fee directly to recyclers (Yin et al., 2013). In Macau, the estimated household average willingness to pay for WEEE recycling is US$ 2.50 per month (Song et al., 2016). There are three possible payment modes for WEEE Advanced Recycling Fees: (1) the cost of participating in a take-back scheme is usually transferred down to consumers (e.g. in the EU); (2) a pre-disposal fee (e.g. in Japan), and (3) a monthly recycling fee for general waste or frequent recyclables (Song et al. 2016). We note that a monthly recycling fee is not relevant for WEEE as its generation is likely episodic rather than persistent (Shaw et al., 2006).

In the UK, Ongondo and Williams (2011a) identified consumers' willingness to increase their WEEE recycling behaviour in response to economic incentives. Even though the existing WEEE legislation offers free take-back schemes, consumers still need to be offered incentives to overcome the associated perceived cost to take back their WEEE (Ongondo & Williams, 2011a). However, when WEEE has little or no residual monetary value, it is not profitable for collection organisations to offer incentives. Furthermore, if EEE still has some residual monetary value, for example when unbroken, consumers can use peer-to-peer (Consumer to Consumer, C2C) websites such as eBay or Amazon Marketplace to resell their unwanted devices. There are also a significant number of for-profit and not-for-profit organisations offering to buy unwanted mobile/smart phones. Online WEEE recycling participation is influenced by consumers' perceived value of monetary incentives and how soon the reward will be triggered (Wang et al., 2021). These studies on WEEE and monetary incentives confirm that monetary rewards have a role, but they are strictly bounded by WEEE secondary monetary value. By essence, this value is decreasing over time, diminishing associated incentives.

Obsolete EEE has limited residual monetary value (Casey et al. 2019). Economic incentives attached to WEEE are necessarily very low as monetary value is estimated on materials, not on potential reuse. Moreover, collection patterns are necessarily different to general waste due to the episodic pattern in which small WEEE and UEEE are generated. Higher monetary incentives for destockpiling of mobile/smart phones exist but for a reuse purpose: if a device is in working order, it still has a monetary value and can be resold, often with little or no need for repair. However, if a device is broken or unusable as is, its estimated value is associated with the value of its secondary material content, which represents only a fraction of the value of working devices (Ongondo & Williams, 2011b). Furthermore, if consumers were satisfied with the resale price for their unwanted and unbroken devices, they would likely use these services more often. Estimates of the refurbished smart phone market differ widely but the numbers of devices are likely to exceed two hundred million (IDC, 2021). Compared with the more than 2 billion units shipped in 2020 and an average 15% recycling rate in developed economies (Ellen McArthur Foundation, 2015), data indicate that many broken and unbroken devices are not being brought back to a collection point.

2.2 Intrinsic motivators

Given the low financial value of end-of-use or end-of-life mobile phones, extrinsic economic incentives appear unlikely to contribute to the collection of unwanted working devices; intrinsic incentives such as environmental or altruistic values are thus more usually considered as a means to enhance collection rates. Intrinsic incentives are more varied than monetary incentives and more complex to define.

The current understanding of incentives for releasing small WEEE or UEEE from stockpiles stems largely from the waste and resources management literature and, more specifically, from household waste recycling studies (Barr and Gilg, 2005; Liu et al., 2019; Nduneseokwu et al., 2017). The factors usually associated with household recycling behaviour include environmental, ethical or altruistic values, and experience in or awareness of recycling schemes. However, the same factors are not necessarily relevant to both household waste recycling and small WEEE such as mobile/smart phones. Echegaray and Hansstein (2017), for example, found that respondents having a positive attitude towards the environment did not necessarily engage in WEEE recycling behaviours.

The intention-behaviour gap is widely acknowledged (Sultan et al., 2020) and has been widely studied (Armitage & Conner, 2001; Echegaray and Hansstein 2017; Wang et al. 2021). Efforts to reduce this gap commonly address factors that are directly linked to behaviour. In this regard, 'behavioural economics' (the study of emotions and perceptions of decisions) (Kahneman and Tversky, 1984; Thaler, 1980) has the potential to contribute to improving incentives to prevent and exploit existing stockpiles.

In this context, the 'endowment effect', a concept within behavioural economics, is pertinent: this concept evaluates the influence of ownership on value evaluations from individuals: "People typically demand more to relinquish the goods they own than they would be willing to pay to acquire these goods" (Morewedge et al., 2009:947). The endowment effect is influenced by the 'status quo bias' (Samuelson & Zeckhauser, 1988) and 'loss aversion' (Kahneman & Tversky, 1984). Individuals tend to prefer remaining in a status quo situation rather than engaging in a transaction with the possibility of losing some attributes associated with owning an object. For example, someone parting from their small WEEE in working order might regret the decision at a later stage but will not be able to reverse it.

2.3 Research aim

This study aims to bring together perspectives in relation to end-of-use/life behaviours and their role in the prevention and exploitation of existing stockpiles of small WEEE and UEEE, with a focus on mobile and smart phones. We aim to evaluate and propose a set of factors that are pertinent to investigation of small WEEE and UEEE end-of-use/life decisions and that present opportunities for enhancement of collection of small WEEE and UEEE for recycling or reuse.

3. METHODOLOGY

To explore and evaluate end-of-use/life behavioural factors in relation to mobile/smart phones, waste and resources management academics and practitioners from around the world were consulted. A list of candidate factors from the literature was compiled and consultees were asked to determine which of these factors were the most relevant for small smart and mobile phones. Online Delphi was used to gather consultee panel input across a large geographical area and to minimize bias induced by other respondents' input.

3.1 Delphi methods

Qualitative data can be accurately generated with Delphi methods (Hsu & Sandford, 2007). It is a consensus-building process developed for the Research And Development (RAND) Corporation in California, USA by Dalkey and Helmer (1963) designed to elicit an expert opinion. Several waste management studies have used this method (Bouzon et al., 2016; Raut et al., 2016) but only one specifically with WEEE (Kim et al., 2013). Panel members are invited to take part in a data collection process involving at least two rounds. Rounds are used to establish consensus iteratively. Data can be collected via interviews, open or semi-open questionnaires or Likert scales to rank factors (Hsu and Sanford, 2007). To avoid groupthink and potential influences in responses, panel members are not aware of others' presence. After a completed round, the information generated by consensus is shared with all panel members. This information is then used by the researcher to elaborate on subsequent rounds. Data collection stops once consensus on the overall aims is achieved. Cut-off points are established by the research team to determine an anticipated level of consensus (Hsu and Sanford, 2007). A limitation of Delphi data collections is the time-consuming process for the panel to convene at certain points in time and the time required for the research team to process the data. However, relevant technology can be used to limit this drawback.

Online questionnaires are regularly used to gather expert opinions in a Delphi setting (Gijsbers et al., 2016; Steinert, 2009; Yeh & Cheng, 2015). Data to be collected are structured by the researcher within web-based survey tools (Gill et al., 2013). Usually, Likert scales are used to rank factors and open / semi-open questions are included to enrich the data collected. This approach reduces survey administration time, enhances opportunities for data analysis, reduces errors and removes physical barriers to participation (Bloor et al., 2015). However, online Delphi has limitations (Donohoe et al., 2012). Some panel members might not have access to the Internet. Hardware or a web-based survey tool could fail and data could be lost. Data collection needs to be scheduled within appropriate time frames as would be done for a physical, onsite data collection event. It also cannot be ensured that invited respondents are those completing the questionnaire; this issue can be mitigated by sending individualised links to respondents. Web-based methods attenuate time-consuming issues associated with other established Delphi methods and, if appropriately selected and designed, can enrich the value of the data collected by using innovative methods associated with decision science.

3.2 Sampling

Using convenience sampling, two hundred and five waste and resource management practitioners as well as researchers from academia, government agencies and the private sector were selected. The potential panel members were part of the co-authors' professional network and were contacted via email inviting them to the study with a personalised message. The potential bias was compounded by the very Delphi method itself: the panel members did not know who were the other participants. The prospective sample had experience and knowledge in WEEE as this segment is an integral part of waste management concerns since so much WEEE fails to be recycled. In 2018, 38.5% of WEEE was landfilled in the European Union (European Commission, 2019). The behavioural aspects of the study did not require any expertise in behavioural science. The questions were related to end-of-use intentions (Table 1) and these results were analysed by the researchers from a behavioural perspective. The prospective panel members were from Western Europe: Germany, Belgium, France, Portugal, Ireland, Austria and the UK. They were presented with the two-round data collection process and invited to take part in the study. Participants were incentivised to engage by accessing early data between rounds one and two. Only members who had participated in round one were invited

TABLE 1: Summary of factors investigated stemming from waste management and behavioural economics literature.

Category	Factors	Source reference
Norms and attitudes	Lack of social pressure	Barr et al. (2001)
	Lack of ethical values	Chan and Bishop (2013)
	Lack of environmental values	Barr et al. (2001)
	Lack of altruistic values	Shaw (2008)
	Lack of positive attitude towards recycling	Thogersen (1994)
Experience and self-efficacy	Limited experience	Barr et al. (2001)
	Complex process	Harder and Woodward (2007)
	Limited awareness	Gutierrez et al. (2010)
Convenience and time	Inconvenient process	Chan and Bishop (2013)
	Time in storage	Gutierrez et al. (2010)
	Time consuming / saving	Saphores et al. (2009)
	Immediate decision	Gutierrez et al. (2010)
	Delayed decision	Gutierrez et al. (2010)
Device characteristics and status	Small size	Perez-Bellis (2015)
	Unbroken device	Barr et al. (2013)
	Quantity in storage	Karim Ghani et al. (2013)
	Device obsolescence	Gottberg et al. (2006)
Behavioural economics	Utility	Thaler and Sustein (2008)
	Regret felt	Tversky and Kahneman (1992)
	Emotional loss	Johnson et al. (2012)
	Lack of positive emotional reward	Carrus et al. (2008)
	Irreversible decision	Ramani and Richard (1993)

to take part in round two. Both rounds took place between February and June 2015.

3.3 Survey design and piloting

Both rounds were piloted among academic and research colleagues with experience and expertise relating to waste and resource management; ten individuals assisted in piloting round one and five for round two. The entire Delphi was administered online. Round one questions were divided into four themes: resell, reuse, recycle and discard; questions were presented in this order to respondents. Factors investigated were selected from the waste management and behavioural economics literature as well as factors related to mobile and smart phone characteristics (Table 1). For example, factors relating to behavioural economics - such as emotional loss, irreversibility of decision, device utility - were included. All categories of questions included characteristics potentially influencing end-of-use/life decisions, such as device size (convenience of storage), time in storage and device obsolescence. For recycling and discarding decisions, environmental values, altruistic values and ethical considerations were presented to panel members (Table 1).

Aspects specific to each category were then investigated, e.g. limited experience or awareness of reselling processes, emotional rewards for giving away a mobile or smart phone, recycling decisions and device status, or convenience of discarding methods. Respondents were also able to make free-text comments. In total, 69 factors were scored by each panel member in round one: 18 for “resell”, 9 for “reuse”, 23 for “recycling” and 19 for “discarding”. For closed questions, a 5-point Likert scale that ran from “strongly agree” to “strongly disagree” was used. During the second round, the PAPRIKA methodology was used (Potentially All Pairwise RanKings of all Alternatives; Hansen & Ombler, 2008), which presents respondents with pairs that are undominated and ranks automatically pairs that are strictly dominated, following transitivity principles (if A>B and B>C, then A>C), which results in fewer decisions for Delphi panel members (Hansen & Ombler, 2008). PAPRIKA derives from the Analytic Hierarchy Process (AHP; Saaty, 1982), a widely-used methodology to organise complex decisions but which results in more decisions (Hansen & Ombler, 2008).

With AHP, three criteria with four alternatives require 64 decisions in total by each panel member (4 x 4 x 4). By comparison, PAPRIKA requires 32 decisions, as the method only presents undominated pairs requiring a decision. To achieve this efficiency PAPRIKA requires criteria to be ranked before data collection. Respondents are presented with pairs that are undominated and the software ranks automatically pairs that are strictly dominated (Hansen and Ombler, 2008). PAPRIKA offers a more natural decision-making process than AHP. Instead of using 10-point Likert scales, panel members are presented with pairs of alternatives and select which pair dominates, or if they are equal. PAPRIKA is a proven methodology that has been used in several studies (Martin-Collado et al., 2015; Nielsen et al., 2014; Smith et al., 2014) and has been made widely available to academics for dissemination (Table 2).

3.4 Procedure and ethical considerations

Participants were given four weeks for each round and a reminder was sent after two weeks. The participant information sheet at the beginning of the survey informed potential participants the survey would require approximately 20 minutes of their time; that they could resume at any time; that all results would be anonymous; and they could withdraw at any time without prior consent. Prospective participants were all informed that by entering the survey they were registering their informed consent.

3.5 Data analysis

Once round one data collection was completed, relevant and non-relevant factors were separated using the Content Validity Ratio (CVR) formula (Lawshe, 1975), according to aggregated Likert scores. This analysis formed the basis for structuring round two of the Delphi survey. A positive CVR value indicated that at least half the panel members were in agreement or in strong agreement with any statement made in the survey. Following Lawshe's (1975) recommendations for panel members above 40, the cut-off point was set at a CVR value of 0.29. Kim et al. (2013), in their Delphi-AHP survey for selecting e-waste priorities, used the same method and cut-off value. The objective of round two was to weigh the importance of factor categories during mobile and smart phone end-of-use decision-making process by comparing them against one another. Following Hansen and Ombler's (2008) PAPRIKA method, factors were ranked according to their Likert scale scores.

4. RESULTS

4.1 Participation in the Delphi survey

Of the two hundred and five participants who were invited to take part in the Delphi study, 103 participants accessed the first round survey and 77 completed both rounds. To be valid, a Delphi data collection requires at least ten panel members (Hsu and Sanford, 2007). Out of all the waste and resources management researchers and practitioners, 39% were from the private sector, 33% from academia and 28% from dedicated government agencies. Most of the panel members came from Western Europe (Table 3). Of these respondents, 44 subsequently completed round two. Response rates were thus 38% and 57% for round one and round two respectively. More than half of respondents had more than ten years of experience in the field of waste and resource management and more than three quarters had more than five years of experience (Table 4).

4.2 Delphi round 1

Based on round one of the Delphi survey, participants cumulatively identified which of the factors extracted from the literature (Table 1) they considered to be relevant to end-of-use/life decisions in relation to mobile/smart phones. Responses received in the first round of the Delphi survey indicated that none of the five factors relating to "norms and attitudes" were considered relevant by the participant group (Table 5). Two of the three factors pertaining to "experience and efficacy" were deemed relevant in this context (Table 5); limitations with regard to reselling were highlighted. Although five factors relating to "convenience and time" were presented, only the time consumed in end-of-life/use actions was considered relevant by the participant group (Table 5). In contrast, several factors relating to "device characteristics and storage" were considered relevant in this context; size, time in storage and utility status were highlighted (Table 5). With regard to the five "behavioural economics" factors, only utility was deemed relevant (Table 5).

4.3 Delphi round 2

The second Delphi round provided an outcome in the form of factors ranked by their importance concerning end-of-use/life decisions for mobile/smart phones (Table 4); ranking was determined using the PAPRIKA method (Hansen and Ombler, 2008). Second round Delphi outcomes were clustered into: (1) factors favouring discarding, (2) factors preventing recycling, and (3) factors preventing reuse (Table 6).

TABLE 2: Decision example for the PAPRIKA method (Hansen & Ombler, 2008).

Decision		
Factors preventing recycling / Device has still utility for the user	> or < or =	**Factors preventing recycling /** Device stored for a significant amount of time
Factors favouring discarding / Time-saving process		**Factors favouring discarding /** Several devices have been stockpiled

TABLE 3: Round 1 panel members' origins (N=103).

Panel members' origin	Proportion
UK	37%
Germany	22%
Belgium	16%
Austria	7%
Portugal	4%
Finland	4%
Ireland	3%
Other	7%

TABLE 4: Round 1 panel members' experience in waste and resources management (N=77).

Round 1 panel members' experience	Proportion
None	3%
1-3 years	3%
3-5 years	16%
5-10 years	23%
>10 years	55%

TABLE 5: Factors identified by Delphi (Round 1) participants as being relevant in end-of-use/life decisions in relation to mobile/smart phones.

Category	Relevant factors identified
Norms and attitudes	None
Experience and self-efficacy	Limited experience in reselling electronic items Limited awareness of reselling opportunities or recycling processes
Convenience and time	Time-consuming
Device characteristics and status	Small product size allows for multiple items to be stockpiled Long time in storage induces a discarding decision Unbroken status prevents recycling decision
Behavioural economics	Low utility for item

TABLE 6: Factors influencing end-of-use/life behaviours for mobile/smart phones. Influencing factors within each cluster are ranked in decreasing order of importance as determined in the Delphi second round applying the PAPRIKA analysis (Hansen and Ombler, 2008).

Cluster	Influencing factors
Factors favouring discarding	1. Discarding is a time-saving/convenient action
	2. Several devices are stockpiled
	3. Device utility is close to zero
	4. Device has been stored for a significant time
Factors preventing recycling	1. Device has been stored for a significant time
	2. Device is not broken
	3. Device retains some utility for the user
	4. Awareness of recycling schemes is limited
Factors preventing reuse/resell	1. Device size allows convenient storage
	2. Reselling is a time-consuming process
	3. Experience in reselling is limited

5. DISCUSSION

The key outcomes of the two Delphi rounds (Table 6) identify, in ranked order, those factors most likely to influence consumers' end-of-use/life decisions regarding mobile/smart phones. These influencing factors are evaluated with previously reported recycling and reuse/resell behaviours.

5.1 Factors favouring discarding

One of the most prominent outcomes from the Delphi survey suggests that discarding is a convenient approach, usually undertaken to destockpile several unused devices, and that the utility for the unused devices is negligible (Table 6). This is in line with several previous WEEE studies.

Wagner et al. (2013) defined 'convenience' according to five main attributes: knowledge of collection system, proximity of collection points, opportunity to engage in the activity, attraction of collection site or method, ease of process. Ongondo and Williams (2011b) support the aspects related to ease of use and identification of collection points, as well as their proximity to points of consumer traffic such as in libraries, banks, or shopping malls. Bouvier and Wagner (2011:1058) advocate a "concerted approach to reduce inconvenience" but the multiplicity of factors and actors required to reduce inconvenience is hard to tackle.

Their small size, frequent replacement cycles and the low numbers of phones reused and recycled imply that more than one device tends to be stockpiled by users (Table 6). This aspect aligns with observations by Ongondo and Williams (2011) who found that 59% of students surveyed stockpiled at least one mobile device; an estimated 3.7 million devices were stockpiled by 2.4 million students in UK higher education in 2011. Several stockpiled devices increase the burden they represent for consumers. An additional phone might serve as a backup but stockpiling at least two additional devices implies excess and redundancy. These unnecessarily stockpiled phones have a high likelihood of being disposed of in general refuse (Gutierrez et al., 2010). Unused stockpiled phones, when stored for a significant time, would more likely be obsolescent, depreciate in value as well as utility.

Unbroken phones tend not to be recycled thereby increasing the number of stockpiled phones (Table 6). When a device is unbroken it has more value as a usable handset, compared with a phone destroyed to retrieve the secondary market value of its components. Ongondo and Williams (2011) estimated that 59% of students replaced their phones because they were broken. Consumers' behaviour is highly influenced by changes in the mobile and smart phone sector in terms of shifts in demand and product preferences. In 2011 Nokia was the global mobile phone market leader with 27% market share and smart phones were barely emerging; Apple had a 3.5% market share at this time (Statista, 2020). At present, Apple and Samsung release flagship models frequently during much-publicised global events largely anticipated by consumers and technology specialists (CES, 2020). In 2019, 1.7 billion smart phones were shipped from factories (IDC, 2020). Whilst the estimated average life span of a mobile phone is significantly longer than smart phones, smart phone shipments exceeded mobile phone shipments in 2013 and the trend is not set to be inverted as consumers use them to "remote control their life" (Economist, 2016). Large manufacturers invest substantial resources in design and performance. These rapid improvements render smart phones released a couple of years ago obsolete and not fit-for-purpose. These factors support the claim that, even though limited data are available on the number of unbroken smart phones, stockpiled mobile devices tend to be unbroken, compared with a trend observed relatively recently by Ongondo and Williams (2011a).

5.2 Factors preventing recycling

Panel members indicated that factors preventing recycling were mostly influenced by the duration the stockpiled mobile device had been left unused, the device's working order status, the residual utility users might have for the device, and the limited awareness some users might have of recycling schemes (Table 6). End-of-use mobile or smart phones, as opposed to end-of-life devices, still have remaining utility and are not considered as waste by consumers (Table 6). These devices at the end of their useful life are stockpiled for potential future use, as a back-up or spare (Ongondo and Williams, 2011b). However, the longer these devices are stockpiled, the more likely they are destined for general refuse as opposed to being recycled (Gutierrez et al., 2010). When devices are collected by take-back schemes, if they are in working order they will likely be reused; if not they will be recycled (Table 6). Recycling is a destructive activity and devices with a residual utility will be stockpiled for a probable future usage. Despite the incentives offered by take-back schemes (Ongondo and Williams, 2011b), such as an offer close to the market valuation or free postage for phones with no monetary value left, users tend not to use such schemes. Ongondo and Williams (2011b) estimated that a majority of online mobile phone take-back schemes are convenient to use but, for students in higher education, usually lack a physical collection point next to high consumer traffic areas such as shopping malls, libraries or campuses.

5.3 Factors preventing reuse and reselling

Among the factors preventing reuse, the device size and the perception of reuse being a time-consuming activity appeared as significant barriers (Table 6). The size aspect connects with the earlier factors favouring discarding as several devices can be stockpiled (§5.1). The small size of mobile and smart phones makes them an ubiquitous item used every day, but when these devices reach their end-of-use/life, they can be stored without any marked impact on storage space (§5.2). This underlines the importance of the device characteristics in the decision-making process. New smart phone prices decline rapidly (Compare and Recyle, 2021). In November 2017 Apple's flagship device, the iPhone X, entered the market but within 3 years its value had halved. There appear to be no studies yet evaluating users' perceptions of second-hand prices. However, we suggest that some consumers might prefer not reselling at a price they believe is significantly lower than their expectation or perhaps considered unfair.

Panel members believe that limited experience of reuse processes has an impact on stockpiling (Table 6). However, experience in mobile and smart phone reuse is increasing. Global smart phone manufacturers now offer refurbished devices alongside new product sales. Van Weelden et al. (2016) argued that designers and marketers should take the lead to change consumer perceptions concerning refurbished mobile phones. The more users are exposed to reuse schemes and hear positive experiences from close friends or relatives or via social media, the more likely they engage with reuse. Stromberg et al. (2016) recommended that trials are necessary to trigger an intended behaviour.

5.4 Overview and recommendations

To fully understand the barriers preventing the collection of UEEE, factors stemming from behavioural studies, such as norms and attitudes or experience and self-efficacy or utility, as well as factors associated with the device characteristics, must be considered. This study finds that new sets of situational factors are required to facilitate desired end-of-use behaviours that enable enhanced resource efficiency for small WEEE and UEEE.

5.4.1 Norms and attitudes

The factors usually investigated infer barriers that are inherent to a lack of values (ethical, environmental, altruistic), lack of social pressure, or lack of positive attitudes towards recycling (Barr et al., 2001; Chan and Bishop, 2013; Shaw and Maynard, 2008; Thogersen, 1996). These studies are mostly aimed at household recycling behaviour and rarely directed towards WEEE or UEEE (e.g. Le Hoang, 2013). Data collected from waste and resources management practitioners and scholars indicate these factors are not relevant when investigating end-of-use decisions or small WEEE and UEEE (Table 6). Echagaray & Hansstein (2017) support the view that household recycling behaviour does not necessarily translate into a similar behaviour for small WEEE and UEEE. The very nature of electronic items, particularly when they retain some form of functionality, may not be considered as "waste" per se.

5.4.2 Experience and self-efficacy, convenience and time

The Delphi panel indicated that a lack of experience and awareness might be contributing factors to small WEEE and UEEE stockpiling decisions (Table 6). This aspect is supported by Barr et al. (2001), Harder and Woodward (2007) and Gutierrez et al. (2010). Lack of practice might hinder a willingness to dispose safely of small end-of-use/life EEE that might still be in working order. The prospect of the necessary process(es) might dissuade users to engage and simply prefer to keep it in a bottom drawer, in effect stockpiling it, perhaps for future use. This aspect is supported by the Delphi panel outcomes indicating that time and convenience are factors that can influence end-of-use/life behaviour (Table 6; Chan and Bishop, 2013; Gutierrez et al., 2010; Saphores et al., 2009).

5.4.3 Device characteristics and status

Several elements taken from the literature were corroborated by the panel members (Table 2; Perez-Bellis, 2015; Barr et al., 2013; Gottberg et al., 2006; Karim Ghani et al., 2013). The size of mobile/smart phones and their working/non-working status are factors that have a strong influence on stockpiling decisions and can be grouped with factors associated with convenience and time. The effect of time on ultimate end-of-use/life decisions is of particular concern (Table 6; Gutierrez et al., 2010). At some point in time, some users will prefer to dispose of their small WEEE or UEEE with general refuse because it has lost its utility and/or is no longer desirable as a possession.

To increase small UEEE and WEEE collection rates, the barriers should be understood to be specifically addressed. Overall, it appears that factors preventing small UEEE and WEEE to be reinserted into the economy, either by reusing, reselling or recycling them, seem to be more closely aligned with the device's characteristics and the utility users have for the device, in addition to factors already acknowledged by the literature (i.e. convenience, awareness and experience). We conclude that (1) factors relating to device characteristics and utility influence end-of-use/life decisions for small UEEE and WEEE, and (2) initiatives to enhance destockpiling of small UEEE and WEEE should therefore recognise and incorporate device-specific characteristics and utility. We recommend that efforts to improve used small UEEE and WEEE collections rates should not overly rely on factors established to be relevant to household recycling behaviour.

6. CONCLUSIONS

This study has successfully revealed the key behavioural factors relating to end-of-use/life mobile/smart phones. A better understanding of the barriers to recycling, reusing and reselling can help to enhance the design of incentives and policies to increase collection rates, effectively unlocking a global "destockpile lifestyle" to realise full value from the reuse and recycling of small UEEE and WEEE. By circulating more UEEE and WEEE devices back into the economy, positive impacts on resources consumption and reduction of environmental impacts will ensue. Insights from global experts in the waste and resources management sector have challenged established views about consumers' end-of-use/life behaviour relating to smart and mobile phones. Factors such as altruism or pro-environmentalism appear to be relatively weak as determinants of end-of-use/life behaviour for smart and mobile phones, but extrinsic, situational factors such as convenience, utility or phone working/non-working status need to be considered with initiatives to enhance small UEEE and WEEE collection rates. The importance of these factors highlights the need to design incentives and policies adapted to specific types of UEEE and WEEE. Applying frameworks stemming from the study of household recycling behaviour appears to be inappropriate when considering smart and mobile phone devices in working order and for which users still have some potential utility. This finding probably applies to other small similar personal and household items. Future research could quantitatively measure the influence these factors have on small UEEE and WEEE stockpiling levels.

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