**University of Southampton**

Faculty of Engineering and Physical Science

School of Engineering

# Contributing to the Circular Economy by Applying Behavioural Economics for Distinct Urban Mines Exploitation

## A mobile and smart phone case study among UK university students

by

**Xavier Pierron**

Thesis for the degree of PhD in Engineering and the Environment

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## Abstract


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In 2017, 2 billion mobile and smart phones were manufactured but only 15% of this number were collected back, indicating there is clear scope for enhanced collection.

To further close the loop for a circular economy, mobile and smart phone collection rates need to increase. A Theory of Endowed Behaviour extends the Theory of Planned Behaviour to shed new light on small electronics end-of-use behaviours among young adults, using mobile and smart phones within the UK Higher Education as a case study. An exploratory mixed method was developed to identify and then confirm relevant end-of-use decision factors for these devices.

Using concepts from Behavioural Economics, the Endowment Effect was been measured on owners' current mobile devices. Students consistently overvalued their phone second-hand monetary value. This overvaluation was in turn correlated to daily screen time. The more time users spent daily using their device, the higher the overvaluation.

Screen time was not only a proxy to the Endowment Effect but as also to the quantity of devices stored away. Respondents with higher screen time had more devices in storage. Certain devices were stockpiled for a specific backup purpose, but others were hoarded for a lack of better alternatives. Screen time can be used as proxy to both the Endowment Effect and the quantity of devices stored away.

Mobile and smart phones Distinct Urban Mines (DUM) are expressed not only by the quantity of devices and their nature but also the reasons they have been stored away. Mobile and smart phones stored away by stockpilers can be assimilated to a 'safety stock' that is not exploitable and devices kept by hoarders to an 'exploitable stock.' From a DUM of 3.4 million devices in the UK Higher Education system, it was estimated that approximately 1 million are exploitable. Some caution should be made as the extrapolation is made to give a sense of the potential available but the sample is biased towards male and overseas students due to the student cohorts studied.

To access this DUM, it is suggested to integrate screen time as a behavioural factor used as a proxy for the Endowment effect and hoarding behaviour. While difficult at this stage to estimate a clear improvement in modelling screen time and the endowment effect, the aim is to provide additional insights into the barriers leading to stockpiling small e-waste. To counter the Endowment Effect, it is proposed to improve existing collection systems using use Choice Architecture and non-monetary incentives.

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# Research Thesis: Declaration of Authorship

| Print name: | Xavier Pierron |
|---|---|

| Title of thesis: | Contributing to the Circular economy by Applying Behavioural Economics for Distinct Urban Mines Exploitation |
|---|---|

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

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# Definitions and Abbreviations

**Analytical Hierarchy Process (AHP)**

Decision-making technique used to analyse complex set of criteria and alternatives.

**Advanced recycling fees (ARF)**

Government-imposed fee on the purchase of new electronic products to fund recycling efforts.

**BIS**

UK department for Business, Innovation and Skills, now renamed the Department for Business, Energy and Industrial Strategy.

**BIT**

Behavioural Insights Team

**Choice Architecture (CA)**

Methods used to influence individuals' decisions towards a desired goal beneficial for them or society.

**Distinct Urban Mine (DUM)**

Anthropogenic concept to define the amount of secondary materials within a delimited urban environment.

**Endowment Effect (EE)**

Monetary overvaluation effect of objects based on ownership.

**E-waste / WEEEE**

Electrical and electronic waste. The term generic e-waste is generally used and the acronym WEEE is tends to refer legislation.

**Loss Aversion (LA)**

Losses equivalent to gains are perceived as inversely proportional to the pleasure of obtaining gains.

**Mobile phone**

Mobile phone without a touch screen

**NUDGES**

iNcentives, Understand mappings, use Defaults, Give feedback, Expect error, Structure complex choices

**Pay-as-you-throw (PAYT)**

Individuals are charged as per the quantity of waste that is discarded.

**Potentially All Pairwise RanKings of all Alternatives (PAPRIKA)**

Decision-making technique based on similar principles as AHP but requiring fewer inputs from respondents.

**Producer Compliance Scheme (PCS)**

Membership organisation stemming from WEEE legislation requiring producers to pay for WEEE recycling.

**Rare Earth Elements (REE)**

Essential compounds for electronics performance

**Small EEE / electronics Producers (SEP)**

Organisations manufacturing mobile and smart phones such as Apple or Samsung.

**Smart phone**

Mobile phone with a touch screen

**Small e-waste / Small WEEE**

Small electronic and electronics smaller than 25 $cm^3$, typically mobile and smart phones.

**UEEE**

Unwanted Electrical and Electronic Equipment still in working order.

**sUEEE**

Small Unwanted Electrical and Electronic Equipment, typically mobile and smart phones at their end-of-use.

**Status Quo Bias (SBQ)**

Preference to not change a situation or context.

**Theory of Planned Behaviour (TPB)**

Psychological concept linking beliefs, behaviour and self-efficacy.

**Theory of Reasoned Action (TRA)**

Psychological concept precluding the theory of planned behaviour linking intentions, attitudes toward behaviour and behaviour.

**Willingness-to-pay (WTP)**

Amount of money individuals or organisations are willing to pay to acquire a product or service in return.

# Executive Summary

In 2017, almost two billion mobile devices were shipped worldwide in a single year and, for the first time, in 2013 more smart phones were shipped than mobile phones (Gartner, 2016; IDC, 2017). In 2013, the European Union (EU) had close to 20 million students in higher education (Eurostat, 2016) and 99% of university students have a smart phone (Ongondo et al. 2016) which are replaced typically between one and four years of use (Deloitte, 2016). The Ellen McArthur Foundation (2012) estimates that less than 15% of mobile and smart phones are currently recycled, despite having one of the most advanced waste management infrastructures, services and legislation.

Tablets are out of scope of this study as their use is not as widespread as mobile and smart phones (yet). In addition, their usage pattern is different from smart phones. Smart phones are compulsively checked every day, especially by students (Cain and Malcom, 2018; Nayak, 2018). PCs and laptops are out of scope as well as young adults spend far more time on mobile devices (Deloitte, 2016) potentially having an influence on devices' perceived utility. Mobile and smart phones are ubiquitous the world over (The Independent, 2014) and represent an ideal product to investigate factors affecting their end-of-use. Findings from this study could be then applied to other and larger electronic items with a screen.

As of 2016 in the EU, the Waste Electrical and Electronic Equipment (WEEE) recast directive requires Member States (MS) to collect the equivalent of 45% of EEE placed on the market during the 3 previous years (Directive 2012/19/EU). This target will rise to 65% in 2019 or 85% of WEEE generated. The EU's Extended Producer Responsibility (EPR) framework places incentives on producers to collect WEEE. In the UK, EEE producers are required to take part in Producers' Compliance Schemes to finance WEEE collection and treatment. Organisations selling EEE to consumers are EEE distributors and those manufacturing EEE are producers. In addition, Distributors need to offer free in-store take back services. EEE distributors can opt out of free in-store take-back systems by joining a Distributor Take-back Scheme (DTS), which requires a fee proportional to the amount of EEE sold annually. These collection systems are designed to channel back any type of WEEE into the circular economy: broken as well as unbroken and unwanted EEE (UEEE).

In general, the larger in size the UEEE or WEEE, the more likely households will arrange for distributors to take back their washing machines, fridges or TVs as keeping them at home takes up valuable space for an item with limited usefulness, especially if broken. If items are unbroken, householders have the possibility to resell or give them away, but the prospect of managing this process could be perceived as cumbersome and the benefits of having large UEEE removed for a small fee is appealing to households. However, for small UEEE (sUEEE), such as mobile or smart phones, users might keep them as they might be useful in the future, either as a replacement or for other reasons.

In the waste and resource management field, the Theory of Planned Behaviour (TPB) has often been used to evaluate household waste management behaviour. This psychological model, stemming from the Theory of Reasoned Action (TRA), seeks correlation between Attitude, Subjective Norm, Perceived Behavioural Control as well as Intentions and Behaviour. The TPB is useful to assess intrinsic motivators that could lead to an intended behaviour. But the link between intentions and behaviour is tenuous (Blake, 1999). Additional factors such as emotions have been used with sometimes more success than the TPB only, but most of these studies relied on self-reported data (Tonglet et al., 2004, Bortoleto et al., 2012, Ramayah et al., 2012). Moreover, behavioural models such as the TRA or TPB have seldom been used to assess WEEE end-of-life, let alone sUEEE end-of-use decisions.

In the few instances when they have been applied to WEEE or UEEE, these models exploring intrinsic motivators mainly describe an intention to recycle and not recycling action *per se*. In the studies associating TPB and WEEE, to alter behaviour, behavioural triggers have not been considered, such as monetary incentives. WEEE and UEEE incentives are different in nature. A product's "broken" or "unbroken" status directly influences its residual value. Cash incentives for collection of e-waste are based on the potential value of secondary materials retrieved after disassembly. Cash incentives to working EEE are based on the device second-hand market value.

Taxes such as Advanced Recycling Fees (ARF) can also be used to influence behaviour. But these marginal levies are used to finance WEEE collection systems and treatment, not to increase collection rates. On the other hand, cash incentives for collection of UEEE are based on devices' second-hand market value. If a market valuation matches sellers' expectations, it may be speculated that they are more likely to part from their UEEE. If a second-hand market value does not match expectations, users might prefer to give it to a family member or friend, or stockpile it for potential future use.

The concept of utility illustrates the subjective value one has for a given object or situation. An individual will have different levels of "preference" compared to other individuals for the same product. Although subjective, this approach can nonetheless be measured quantitatively using Likert scales and differences between estimated (subjective) and market value (objective). Utility and biased decision-making are fundamental aspects of behavioural economics (Kahneman and Tversky, 1991). This field of research considers biases in the decision-making process leading to “irrational” behaviours, as opposed to “rational” behaviours and decisions purely based on economic gains. For example, it can be assumed that the longer UEEE is stockpiled, the more its market value diminishes and the less likely it will be resold. This goes against conventional rational behaviour where agents tend to optimise their returns (Ariely, 2009). If UEEE is stockpiled and not resold or given away, this could mean that these alternatives are not satisfactory for mobile and smart phone end users. Their perceived utility for the device could be higher when stored away, rather than sold at a value lower than expected.

Given that less than 20% of e-waste is recycled worldwide (United Nations, 2017), this bottleneck warrants further investigation. Young adults have high mobile and smart phone ownership levels and tend to replace mobile technology before it breaks (Ongondo and Williams, 2011). Young adults are considered to be avid consumers of technology (Lenhart et al., 2010) and the habits they develop today will set tomorrow’s consumption trends (Hino, 2015). University campuses represent distinct urban areas that could be used to investigate end-of-use decisions for these devices. Therefore, this study aims to elucidate behavioural factors that influence the storage of small electronic devices, using mobile and smart phones among university students as a case study. Students are used a sub-segment of young adults.

Ongondo and Williams (2011) considered consumer variables intrinsic to the owner such as size and storage space and product variables related to a device’s status (such as reusability and perceived value) to map factors influencing WEEE takeback decisions. The focus was on TVs, a larger type of e-waste. For sUEEE it is suggested inverting consumer and product variables: reusability and perceived value would be associated to the utility a consumer has for the device. Device size and storage space would be linked to product variables. Using Ongondo’s thesis (Ongondo, 2011) as a corner stone, it is proposed to specifically investigate the influence of mobile and smart phone usage on sUEEE end-of-use decisions.

A review of the literature relating to waste / resource management and behavioural economics was undertaken to determine which behavioural factors would merit investigation for mobile and smart phones. Then, the factors of interest were submitted to a Delphi panel to select the factors that would later be quantitatively measured with a social survey. Only a minority of studies directly addressed electronics and a handful small electronics. The Delphi study revealed that end-of-use decisions for mobile and smart phones are influenced by a device's characteristics, such as size, and user preferences for the device, such as utility.

After this qualitative phase, designed to explore the variables of interest, a quantitative phase to confirm the association between behavioural factors and end-of-use decisions for mobile and smart phones was under taken among students from two UK universities. Compared to studies from the literature review and to potentially improve the link between intention and behaviour, respondents were asked to report on current and past behaviour, not intentions they might have in the future.

The quantitative phase unveiled that the amount of time spent daily using a mobile device, referred to as screen time in this study, had a higher correlation level than the concept of utility, as initially believed. Respondents who reported high screen time with more than five hours daily were more likely to have several devices stored. A distinction was made between stockpiling and hoarding decisions. Stockpilers have a single backup phone used for a specific purpose and hoarders have several unwanted devices but are unsure what to do with them. This differentiation is essential as it will allow the distinction between stocks that can be exploited within a Distinct Urban Mine.

The Endowment Effect is the overvaluation of objects owned by users (Tversky and Kahneman, 1991). It was identified and measured in this study. Respondents were asked to evaluate the second-hand monetary value of their device at the time of the survey and then compare with the actual market-based second-hand valuation. Students with high screen time demonstrated a higher endowment effect. The more time they spent daily on their mobile device, the more they overestimated the device's second-hand value. Following these results, it was proposed to modify the Theory of Planned Behaviour (Ajzen, 1985) for small electronics and insert behavioural factors related to mobile and smart phones characteristics and user preferences. More specifically, the inclusion of screen-time and the endowment effect have the potential to increase the link between intentions and behaviour for small electronics end-of-use decisions.

Finally, a critical discussion based on the learnings from the literature review, the qualitative results from the Delphi survey and the quantitative analysis from the social survey was undertaken to identify how mobile and smart phones producers could recognize the influence of the endowment effect on end-of-use decisions and adapt their practice to prevent hoarding and exploit Distinct Urban Mines composed of hoarded devices.

# Chapter 1 Introduction

E-waste is the fastest growing waste stream (Sun et al., 2015) due a combination of increase in electronic product shipments and stagnation of collection and recycling rates, despite having one of the most advanced WEEE legislation and dynamic, open markets for second-hand products.

In the EU, the term WEEE is often preferred for Waste Electrical and Electronic Equipment. WEEE includes end-of-life electrical and electronic appliances which are “dependent on electric currents or electromagnetic fields” (Directive 2002/96/EC). Small WEEE (sWEEE) items (smaller than 25 cm3, Directive 2012/19/EU) are considered one of the least recycled WEEE products (Ellen McArthur Foundation, 2014). Mobile and smart phones pertain to WEEE Category 3 (Directive 2002/96/EC) (Table 1.1).

Table 1.1 Products and equipment in WEEE category 3 (mobile phones in bold)

| Category 3 WEEE | |
|---|---|
| IT and computing products | Centralised data processing, Mainframes, Minicomputers, Printer units, Personal computers (CPU, mouse, screen and keyboard included), Laptop computers (CPU, mouse, screen and keyboard included), Notebook computers, Printers, Tablets |
| Telecommunication equipment | User terminals and systems, Facsimile, Telex, Telephones (including Pay telephones, Cordless telephones & **Mobiles**), Answering systems. |
| Others | Copying equipment, Electrical and electronic typewriters, |

In 2016, more than 45 million tonnes of e-waste were generated (United Nations, 2017). Mobile and smart phones only weigh a few hundred grams at most and individually they now surpass the number of humans on earth with an estimated 7.2 billion devices in activity (The Independent, 2014). Close to two billion mobile and smart phones were shipped in 2017 (Figure 1.1) and since 2013, smart phone shipments outpaced mobile phones. Whilst sales tend to remain stable, smart phones now represent 75% of mobile shipments from just a fraction in 2008 (Figure 1.1). The ubiquitous nature of electronic handsets contributes to high ownership levels. This is exemplified by students. According to Ongondo and Williams (2011b) in 2010 there were 2.4 million students in the United Kingdom (UK) with their ownership level for mobile handsets reaching 99%. It has been determined that students own on average 1.5 devices and will usually replace them within a three-year period, before their non-working state is reached. There are at least an estimated 3.7 million mobile handsets being stockpiled by students in the UK (Ongondo & Williams 2011b). Silveira and Chang (2010) evaluated that between 50 and 90 million devices were stockpiled worldwide.

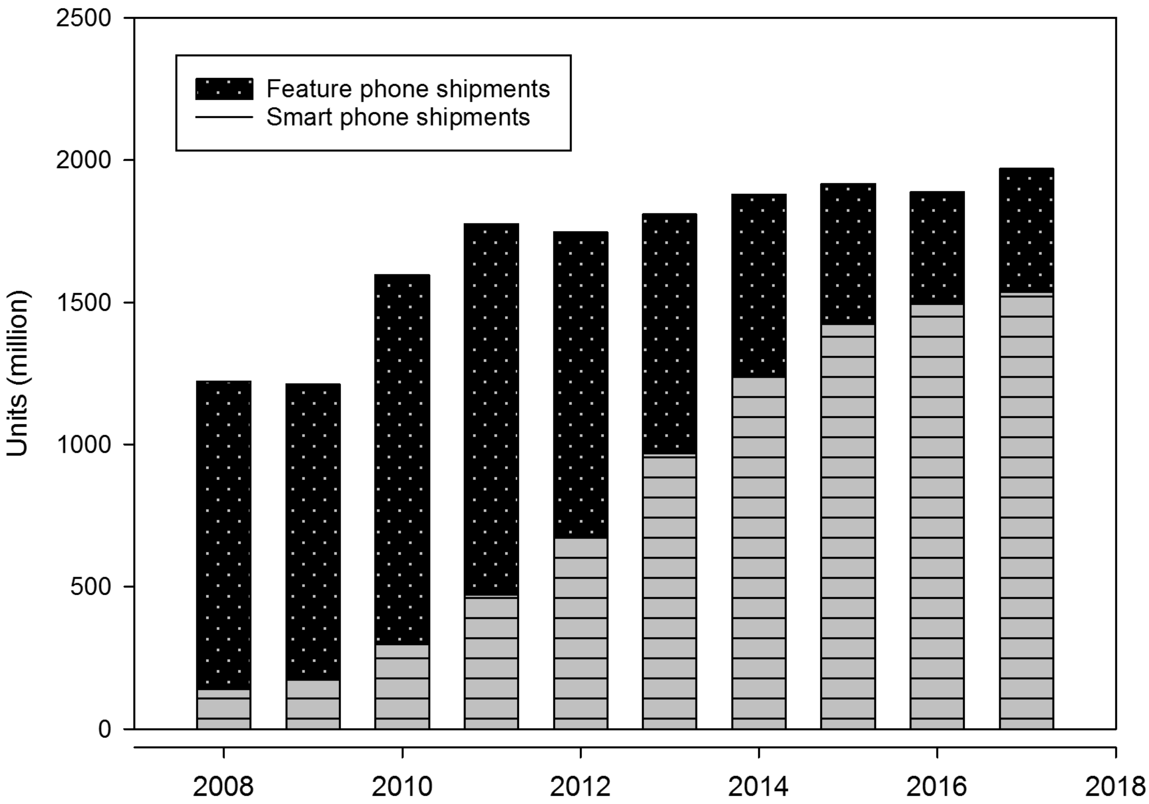


Figure 1.1 Mobile and smart phone global yearly shipments in millions of units (Source: Gartner, 2018)

The Ellen McArthur Foundation (2012) estimated that 10-15% of mobile and smart phones are recycled. Accurate figures are difficult to obtain, but the most optimistic estimate is that 20% are recycled in the UK (Green Alliance, 2015), whilst in the United States of America (USA), the Environmental Protection Agency's estimate is more conservative at 10% (EPA, 2013). The increase in global shipments and low recycling rates mean that several hundreds of millions of mobile and smart phones most likely end - unnecessarily - in landfills. It was estimated in 2010 that more than 130 million mobile phones were discarded in the USA (Electronic Takeback, 2016). E-waste is considered the fastest growing solid waste segment (Oswald & Reller, 2011). In 2016 44.7 million metric tonnes of e-waste were generated worldwide – the equivalent of 4,500 Eiffel towers, up 8% from the previous year (United Nations University, 2017). “E-waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use.” (Step, 2014:4).

Despite WEEE category 3 (Table 1.1) being one of the most collected category at 58% of EEE Placed on Market (PoM) in 2015 (Eurostat, 2016), mobile and smart phones collection rates remained at 15% on average in 2012 (Ellen McArthur Foundation, 2013. It should be noted that there are no reliable statistics on the quantity of mobile and smart phones collected and recycled in the EU. Eurostat provide data for WEEE category 3 in general and the latest available data in 2018 dates from 2015 (Eurostat, 2018). This difference could be explained by the fact that mobile and smart phones represent a marginal share in weight calculation compared with laptops and personal computers (PCs), weighing several kilograms, as compared with less than 200 grams on average for a smart phone (GSM Arena, 2016). E-waste failing to enter the recycling chain either goes to landfill with potentially adverse environmental consequences, or is incinerated, failing to produce any financial or material value. When WEEE is disposed of alongside non-hazardous waste and taken to landfill, metals, plastics and fire retardants can cause environmental contamination (Barba-Gutierrez et al., 2009). Disposing of WEEE in landfill also means raw materials used in the production of EEE are lost (Oguchi et al., 2008, instead of being recovered and reinserted back into a closed-loop system. Other issues include the adverse environmental and health impacts when WEEE is sold illegally to developing countries, where health and safety regulation is lacking and the labour force is poorly trained (Robinson, 2009). The effects on human health are still not well understood; however, the Chinese town of Guiyu and Accra in Ghana are well-known case studies (Daum et al., 2017). These cities are the e-waste recycling capitals of the world (Li et al., 2007). Currently researchers have noted the very high concentration of highly toxic pollutants in the surrounding soils and water (Milovantseva and Saphores, 2013). Song and Li (2015) have investigated the presence of heavy metals in human tissue of people living and working in unregulated e-waste sorting facilities in China.

E-waste represents an environmental challenge but also an opportunity for countries with limited strategic and critical materials availability. According to the European Commission (2010), critical materials are defined by their economic importance and their supply risks due to political risk. Substitutability of the materials and recycling rates are also considered. For example, when a raw material has been identified as critical, it means its supply is almost impossible within the EU and its supply chain outside of the EU could be compromised in the future due to geopolitical reasons or distortions between offer and demand (European Commission, 2010, 2014). In 2010 the

European Commission (EC) released a report on Critical Materials for the European Union (EU), identifying 14 out of 41 non-energy and non-agricultural materials vital for the EU economy associated with high supply risk disruptions. In 2014, an update of the report included 20 materials out of 20, with only one from the previous list being dropped.

The Oko Institute (2011) acknowledges that more efforts on collection rates and recycling technologies must be devoted to achieving sustainable goals in Europe. Leading Japanese manufacturers such as Mitsubishi and Toyota have started vast Rare Earths recycling programmes from batteries, magnets and low energy light bulbs (Toyota, 2014). EEE that eventually becomes category 3 WEEE uses minute quantities of Rare Earths Elements (REE) – compared with electrical cars or wind turbines; however, the mass recycling of these products could generate a substantial amount of REE (Oswald and Reller, 2011; UNEP, 2011), given the hundreds of millions of devices unused or discarded (Alamgir et al., 2012). REE extraction from mobile and smart phones is economically feasible if implemented on a very large scale. Only minute amounts of REE can be retrieved from each device. The now defunct South Korean Economic Institute (SERI) estimated in 2011 that in South Korea alone, 85,000 tons of rare earths oxides were available within South Korean borders, if Rare Earths could be retrieved from recycled e-waste (Korea JoongAng Daily, 2011). This is of particular importance as South Korea does not have direct access to REE and relies on imports from China and Japan. If these resources could be tapped into through recycling it would represent more than 20 times South Korea's annual consumption. SERI was one of the first institutes to encourage urban mining to sustain strategic supplies of materials.

In September 2010, China halted shipments of REE to Japan, its largest customer, amid a diplomatic row (Bloomberg, 2010). Rare earth elements are used to manufacture electronics and green technology products such as hybrid cars or wind turbines with China producing 97% of these materials (Massari and Ruberti, 2013). Not only did REE prices surge (Bradsher, 2014) but the European Commission, the USA and other advanced economies expressed deep concerns over the supply of these materials and subsequently placed them on their critical lists (European Commission, 2010; US Department of Energy, 2010). The World Trade Organisation (WTO) eventually ruled in 2014 that China had unlawfully halted shipments REE shipments and breached its WTO obligations. China did not appeal against the decision. (WTO, 2014).
Hence e-waste is both an environmental threat and a resource access opportunity that might still be underestimated, perhaps due to the inherent difficulties of collecting small e- waste and subsequently processing it to secure specific resources. Electronic waste legislation has been updated to adapt to societal changes, but will that be enough to continue the transition towards a circular economy?

# Chapter 2: Literature Review

The chapter aims to evaluate and analyse critically current behavioural models associated with end-of-use decision-making regarding mobile and smart phones; by analysing end-of-use behavioural models from the waste and resource management literature and by critically appraising key factors involved in these behavioural models.
This chapter reviews the EU WEEE legislation impacts on collection rates and its contribution to the circular economy, its application in the UK, end-of-use behaviour models used in the waste and resource management literature, behaviour change using extrinsic motivators and concepts related to behavioural economics such as the endowment effect and choice architecture. The chapter concludes via identification of research needs and priorities in the waste and resource management literature.

## 2.1 EU WEEE legislation to achieve a circular economy?

The EU's WEEE directives are influencing circular economy priorities in a retrospective fashion: in 2012 the WEEE Directive Recast (Directive 2012/19/EU), setting targets after 2019, was introduced before the European Commission adopted a circular economy approach in 2017 (EC COM (2016) 739). Hence the prevailing legislative framework might not be best adapted to answer tomorrow's needs. The WEEE recast has set more ambitious targets and reduced some of the administrative reporting burden on producers. Nevertheless, to increase significantly recycling rates by further transferring material stocks into flows, anthropogenic concepts such as urban mining and behavioural concepts such as behaviour change might well be necessary. The legislative framework is a top-down approach which has resulted in the creation of efficient collection systems. However, most of the stock is in hibernation within household (Wilson et al., 2017). Bottom-up efforts to alter individual behaviour are necessary to feed into existing collection systems and reinject products and materials into the economy. Both approaches are necessary to improve collection rates.

The circular economy concept emerged from a vision of an economy in loops (Stahel, 1977). This concept resurged recently with growing concerns over environmental issues and resource scarcity (Singh and Ordonez, 2015). The circular economy framework is now at the core of the European Commission's (EC) long-term strategy with the adoption of the Circular Economy Package strategy for a resource-efficient Europe (COM/2015/0614). It follows a cradle-to-cradle approach from the beginning of products' life to waste recycling (plastic, food, construction and demolition), as well as advocating reduce and reuse. The package also includes aspects relevant to the supply of critical raw materials, which has been a source of concern over recent years (WTO, 2014). Ambitious common targets have been set for all Member States (MS) for waste and packaging recycling. The EC has also set an action plan between 2016 and 2019 to help achieve these objectives. WEEE is a potentially sustainable source of plastic, metals and critical materials which could provide a long-term supply of secondary materials (Dirk et al. (2014).

Since its release in 2002, to follow societal evolution and correct initial design flaws, the initial WEEE directive (Directive 2002/94/EC) has been received two minor updates (2006 and 2009) and one major update (Directive 2012/19/EU) to review target collection calculations in 2012. Initially set at 4 kg of WEEE per inhabitant for each member state (MS), the Directive requires (from 2016 to 2018) the collection of 45% of EEE placed on market (POM) in the 3 previous years. By 2019, MS are required to increase collection targets to 65% of POM or 85% of WEEE generated on the territory of that MS. In addition to implementing more comprehensive and ambitious targets, solar panels and LEDs are now included in EEE and EEE distributors such as retailers with sales areas over 400 $m^2$ need to offer small WEEE collection (less than 25 $cm^3$), such as mobile and smart phones.

Article 3 (Directive 2002/94/EC; Directive 2004/79/EC)) defines an EEE producer or distributor as: “any person who, irrespective of the selling technique used, including by means of any distance who:

Manufactures and sells electrical and electronic equipment under his own brand,

Resells, under his own brand, equipment produced by other suppliers, or

Imports or exports electrical or electronic equipment on a professional basis into a member state”

The WEEE Extended Producer Responsibility (EPR) system introduces liability, economic responsibility, physical responsibility and informative responsibility to producers (Directive 2002/94/EC). This directive also follows the 3R waste hierarchy of “reduce, reuse, and recycle” (Cahill et al., 2011), which focuses on sustainability with an integrated approach from a most preferred to a least preferred classification, thus with a preference for reducing and reusing, with recycling as the last resort (United States Environmental Protection Agency (EPA), 2013). However, Ongondo and Williams (2011) and Huisman (2013) identified that WEEE data accuracy is an issue that needs to be addressed. It is also difficult to obtain recent data. Consequently, the enforced directive (Directive 2002/94/EC) should increase collection costs by up to EUR 1 billion for producers who will pass them on to consumers. It will also reduce atmospheric environmental harm by increasing the quantity of safely treated WEEE.

From 2005 to 2008, the EU required its Member States to transfer into national legislation its WEEE directive (Directive 2002/94/EC). China specifically incorporated the concept of circular economy into legislation in 2008 to mitigate environmental issues (Su et al., 2013). The USA has been slower than Scandinavian countries and the EU to adopt circular economy concepts but companies are now increasing their raw materials supplies from secondary recycled materials, as illustrated in the car industry using more recycled aluminium to reduce price volatility (The Guardian, 2015). China has integrated the Circular Economy concept in its legislative framework as a way to tackle environmental challenges posed by the break neck economic growth (Su et al., 2013)

The European Commission reiterated its support towards a circular economy with the WEEE recast in 2012 by setting targets better adapted to business realities and reducing the administrative burden of compliance (BIS, 2012). Furthermore, the EC Ecodirective (Directive 2009/125/EC), initially implemented to increase EEE energy efficiency, gradually evolved towards favouring Circular Economy principles with a focus on extending products lifetime. Several subsequent consultations placed emphasis on product reparability, upgradability and design for disassembly (European Parliament, 2019). Creating legislative frameworks has motivated EU Member States to progress from approximately 2.5 kg of WEEE collected per year per inhabitant in 2005 to more than 7.6 kg in 2016 (Figure 2.1). Forty-five percent of POM represents 11.6 kg per inhabitant in the EU and Huisman (2010) calculated that a 65% of EEE POM in 2016 would equal to 16.7 kg. Moving from weight-based targets towards quantity-based targets is an improvement. EEE product weight is constantly dropping, especially for small WEEE, making weight-based even less relevant. Another aspect arguing against weight-based evaluation is the association of minute quantities of Rare Earths Elements to improve electronic performances for EEE (Eliseeva and Bunzli, 2010). This increases the potential value of WEEE whilst it increases the entropy of the system.

In addition to strategic governmental efforts, private entities and business have taken proactive steps to harness their efforts towards a common goal. The Ellen McArthur Foundation (Ellen McArthur Foundation, 2018) and its association to McKinsey & Company, a consultancy, have been instrumental in building awareness and linking theory to practice. In addition to showcasing efforts from private organisations, they engage government and large corporations such Cisco to commit to sustainable development. An example of applied circular economy from the Ellen McArthur Foundation (2016) is Re-Tek. The organisation employs 32 people in the UK and specialises in refurbishing and reselling Internet Communication Technology (ICT). It processed 170,000 devices in 2016. The Green Alliance (2015) estimates that used and refurbished smartphones will have reached 257 million in 2018, from 53 million in 2013. However, Deloitte (2016) estimated the number of refurbished phones would be set at 140 million units. Nevertheless, to achieve these ambitious top-down targets set by the WEEE Directive recast by 2019, other complementary elements stemming from bottom-up initiatives are necessary to capture efforts from all directions.

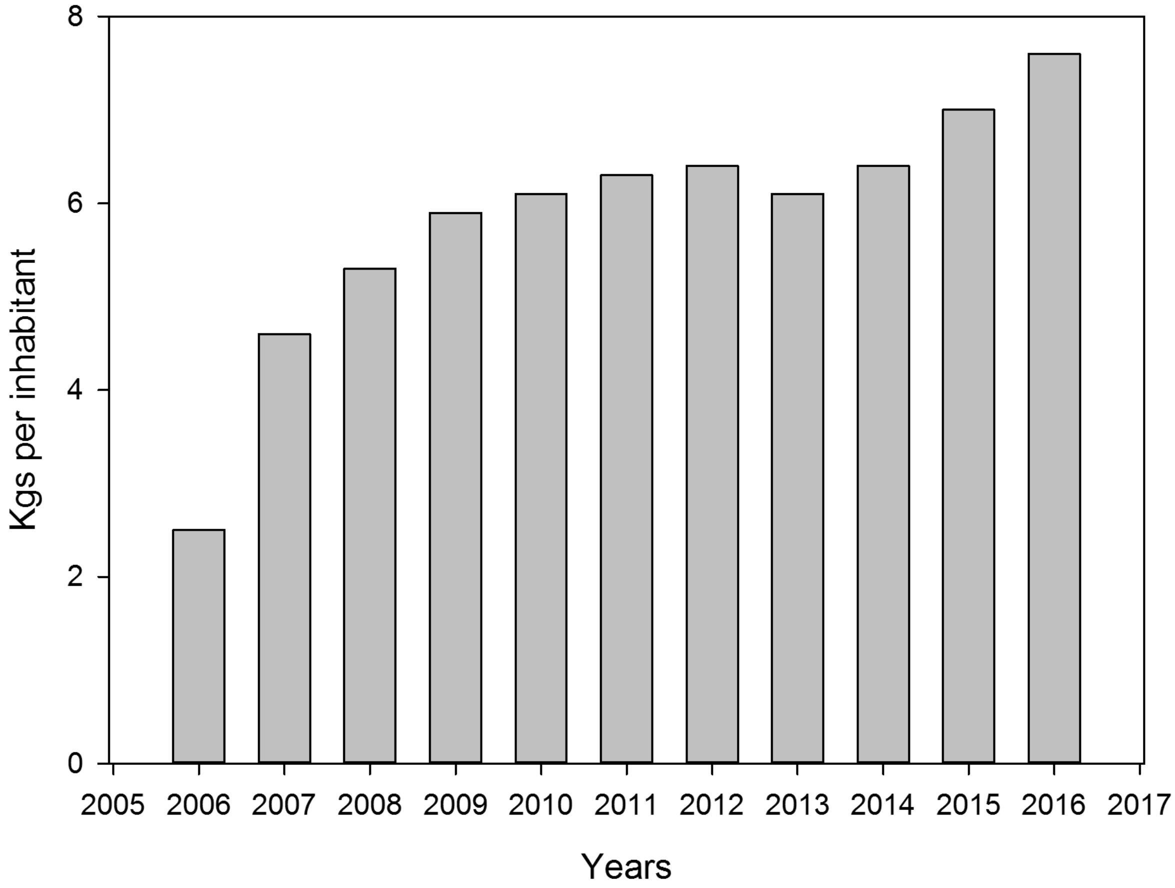


Figure 2.1 EU average WEEE collection per inhabitant per year (Source: Eurostat, 2016). Y axis 'WEEE collection per inhabitant (kg / year)' X axis 'Year'

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## 2.2 WEEE Directive application overview in the UK

WEEE legislation stemming from EU directives represents a sound basis to harmonise efforts and targets among European states. However, given the disparate nature of WEEE with its many forms, shapes, weights and composition, a homogeneous approach to collecting it will necessarily pose many challenges, perhaps especially for small WEEE and more specifically for mobile and smart phones. Trivial examples would be that smart phones can be posted but not a large TV; two people would be needed to move a washing machine but a small child could carry multiple LED bulbs that are not working.

The WEEE Directive 2002/96/EC drives the re-use and recycling of WEEE and was implemented in the UK law by the WEEE Amendment Regulations (2009). WEEE legislation places a legal obligation on EEE producers to finance the treatment, recovery, and recycling of WEEE at approved treatment facilities by joining a producers' compliance scheme (PCS). Distributors (including retailers) of EEE must also either join a distributor TBS or take back like for like WEEE from customers in store (BERR, 2008). The distributor TBS finances the collection of WEEE at Designated Collection Facilities (DCF), which some household waste recycling centres (HWRC) have been designated as by local authorities (LA). There is however no legal obligation for LAs to collect WEEE (BERR, 2008). In addition to placing a financial burden on producers as per the EPR (Directive 2002/94/EC)., it places a share of this effort on distributors to finance the upgrade and maintenance of WEEE collection systems within British DCF. Local Authorities manage DCF; however, they have no enforcement role with regards to WEEE regulations. Cahill et al. (2011), when comparing several member states, saw this situation as a flaw in the initial legislative design.

Before translating the WEEE directive recast into regulation, the UK government – via the Department for Business, Innovation and Skills (BIS) and with the involvement from DEFRA, as well as the Welsh and Scottish devolved governments, organised a consultation between April 2013 and June 2013 with major WEEE stakeholders (BIS, 2013). This consultation addressed one of the previous shortcomings of the lack of central direction. It gave WEEE collecting and recycling stakeholders, who were willing to take part in the process, a possibility to influence legislation to potentially improve the current situation (Cahill et al., 2011).

The UK consultation did not result in an improvement in the estimation of WEEE collected and treated to increase data reliability. This issue was previously flagged by Ongondo and Williams (2011) and Huisman (2013). Unclear WEEE estimates are a flaw in any compliance calculation methods. Huisman (2013) warned of the pressure from competition to lower compliance costs at the detriment of quality of treatment.

The implementation of the WEEE Directive by Member States has been successful to a certain extent. The circular economy concept only appeared recently at the core of the European Commission's long-term strategy and legislative frameworks might not be sufficient to achieve these ambitious targets. The EU's WEEE legislation provides obligations to producers to offer collection methods for free, but it is not producing incentives for consumers to bring back their WEEE to collection points, especially when small WEEE can be conveniently stockpiled. It has initiated the flow of materials back to recyclers but it is not yet enough to consider it a circular economy. WEEE regulation addresses waste but in most cases when EEE is replaced it is unwanted and still working, especially for small items, and hence most people would not call it "waste" (Ongondo and Williams, 2011), despite being recognised as by the Waste Framework (Directive/2018/851). Second-hand markets with take-back schemes (TBS) and peer-to-peer sales address unwanted EEE. But stockpiling levels (Ongondo and Williams, 2011) indicate a gap that needs to be bridged to further the progress towards circular economy ambitions.

## 2.3 Urban mining as the link between circular economy objectives and individuals' behaviour change?

Urban mining is the process of reclaiming compounds and elements from products, building and waste. It is a useful construct that facilitates an assessment of secondary materials stocks within an urban environment since it delimits an area in which the type/amount of materials accessible at a fixed point in time can be recorded. In this context, the concept of accessibility is expressed by the overlapping of available materials and their approachability (Mueller et al., 2017). These estimates can then be used to measure the investments necessary to retrieve materials. "WEEE is the backbone stream in urban mining" (Cossu and Williams, 2015:3). Yao and Steemers (2004) have specifically studied small household appliance (WEEE category 2) ownership levels. Ongondo et al. (2015) have estimated WEEE stocks and flows within a university's campus and proposed the concept of Distinct Urban Mines (DUMs). DUMs are not only defined by their delimited space within the anthroposphere but also by the potential availability and accessibility (Mueller et al., 2017) of resources for a given type of EEE. For a specific UK university DUM rich in EEE category 3 (IT and telecommunication equipment), it has been estimated that 107 tonnes of secondary materials could be exploitable within a 4-year cycle. Given the nature of higher education with 3 to 4 years cycles to complete a degree, the replenishment rate can therefore be estimated between 25% and 33% (Ongondo and Williams, 2011). Pierron et al. (2016, 2017) have estimated that 189 tonnes of ferrous and non-ferrous materials from WEEE Category 2 could be exploitable within a Distinct Urban Mine from a university campus. There is clear economical potential for developing urban mines from household stockpiled small WEEE (Pierron et al., 2014, 2015). To be exploitable a mine (urban or not) needs to be economically viable and located within reach of an existing logistics network with materials concentration at an optimal level (Zhang and Kleit, 2016). Therefore, a DUM is a valid concept to evaluate: i) the potential to secure secondary resources from within the anthroposphere and ii) the possible cost-efficient methods that could be implemented to access them.

In a sense, urban mining has already been applied in many areas; it is simply a question of scale not yet achieved. WEEE collection events are regularly organised at community levels (WRAP, 2016) and by private organisations (Veolia UK, 2016). Collection events have households bringing back to a single location at a specific time their WEEE. These events are mainly aimed at smaller WEEE, as larger WEEE is often taken away when a new product is delivered (Directive 2002/96/EC; Directive 2012/19/EU). However, it is estimated that several millions of mobile and smart phones are still stockpiled in the UK (Ongondo and Williams, 2011) and the European Commission estimates that in 2012, approximately the equivalent of 42% of all EEE placed on the market was collected (Eurostat, 2016).

Cossu and Williams (2015) place urban mining as the intermediary step between landfill mining and materials recycling. Di Maria et al. (2013) estimated that landfill mining Residual Municipal Solid Waste (RMSW) yielded less than 2% of WEEE related materials. Materials recycling is associated with industrial processes crushing and separating out materials using physical and chemical methods. Urban mining is associated with diverting out-of-use objects from general refuse and directing them towards recycling facilities. However, urban mining is still in its infancy and more research is needed to expand this field (Krook and Baas, 2013). From an extensive literature review on urban mining Krook and Baas (2013) have identified four research streams: metabolic flows (materials stocks), business dynamics (profit seeking), governance and knowledge (regulation and legislation), infrastructure and markets (resource recovery as a market in itself). These studies connect with business dynamics and how consumers could be incentivised to participate in urban mining efforts. Krook et al. (2011) and Wallsten et al., (2015) in their research on exploiting copper from power grids in Sweden, acknowledge that for urban mining activities to be profitable, they need to be coupled with other planned activities; in this case maintenance operations.

Simoni et al. (2015) expressed mixed views on successful urban mining activities in Switzerland. They acknowledge that urban mining can only be successful if public waste management efforts and policy-making are supporting urban mining activities to enhance its potential, especially as the costs associated with recycling REE are currently higher than primary mining, making sole economic profit seeking less relevant in this case. Moreover, there are not yet technical methods to recycle REE from small e-waste safely and economically (Binnemans et al., 2013). Rare Earth Elements from larger items such as from electric vehicles can be recycled safely and economically into smaller 3D printed magnets (Recycling Today, 2018).

Gutberlet (2015) in her study on informal urban mining in Brazil highlighted a need to structure and steer individual actions toward a sustainable development. Sun et al. (2015) and Tunsu et al. (2015) recognise that WEEE category 3 is a strategic source of secondary materials. More specifically permanent magnet scrap from Internet Communication Technology (ICT), such as mobile or smart phones, represent valuable sources of secondary rare earths, when processed by specialised recycling plants.

Distinct Urban Mining might be a useful concept to assess existing secondary materials stocks. Flows have been initiated by WEEE legislation but other methods, perhaps less centralised, need to be explored to further induce consumers to bring back their WEEE (broken) and UEEE (working) to a collection point. Waste management and environmental behaviour authors have investigated intrinsic motivators leading or impending household recycling behaviour. Their research aims at developing models attempting to explain end-of-use behaviour among individuals. These models are elaborated onto intrinsic motivators, such as social norms or attitudes. As opposed to extrinsic motivators such as economic rewards.

## 2.4 Waste management behaviour theory and intrinsic motivators

Behavioural models are gradually built on the successes and limits set by previous models. Fishbein and Ajzen (1975) and Ajzen (1985) have developed models based on psychological principles: Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB) respectively. They are based on intrinsic motivators such as beliefs, attitudes, intentions, social norms, awareness of consequences. Recent developments have indicated that models associated with emotions, feelings and desires reached higher levels of statistically explained variance than models using TPB and environmental factors. A short review of different models used in waste management and environmental behaviour is presented in Table 2.1. The common denominator between these studies is the use of the TPB. Studies use TPB factors as the core and explore other variables of interest depending on the study focus (Table 2.1). The field of psychology that is associated with consumer behaviour has been used in the past to attempt predicting recycling behaviour. In 1975, Fishbein and Ajzen published their seminal paper on the theory of reasoned action (TRA) using beliefs, attitudes and intentions to predict human behaviour (Figure 2.2). The framework associates attitudes towards the act with intrinsic motivators such as subjective norms to determine behavioural intentions, which the researchers believe translate into behaviour.

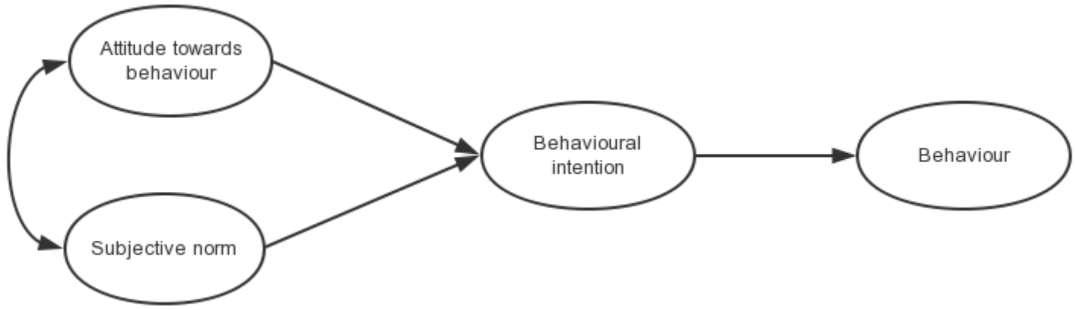



Figure 2.2 Theory of Reasoned Action and factors influencing intentions (Redrawn after: Fishbein and Ajzen, 1975).

To reduce the TRA's gap between intentions and behaviour, Ajzen (1985) added perceived behavioural control (PBC) to attitude and subjective norms, resulting in the Theory of Planned Behaviour (Figure 2.3). PBC is the perception of the ease or difficulty of the specific behavior, which mitigates or enhances the perception towards a behaviour and the social pressure to execute (or not) an identified behaviour (Ajzen, 1991). In this framework, the notion is that control enhances behaviour as skills, abilities, knowledge, and adequate planning are added (Davies et al., 2002). Individuals assess potential actions against their consequences and perceived value; the decision-making process is influenced by the "acquisition, evaluation, execution and interruption of abstract actions" (Balleine et al., 2015:2). But behaviour is difficult to predict accurately and is an unsteady process (Bouton, 2014). Individuals tend to follow behavioural patterns but they can change their behaviours for various reasons. Therefore, anticipating accurately individuals' actions is science as well as art, ascription of responsibility, personal norms, past behaviour and values.

To date, the TPB has been widely used in a variety of fields: health-care, psychology, decision analysis, consumer behaviour (Ajzen, 2011), and waste management (Hopper and Nielsen, 1991; Davies et al., 2002; Richetin et al., 2010; Ojedokun, 2011; Chan and Bishop, 2013; Pakpour et al., 2014; Wan et al., 2014; de Leeuw et al., 2015). Despite its popularity, the model yields a wide range of explained variance in behaviour. Armitage and Conner (2001) in their TPB meta-analysis calculated that TPB accounted for 27% and 39% of the variance in behaviour and intention. Therefore, researchers tend to add variables in addition to the TPB core (Table 2.1).

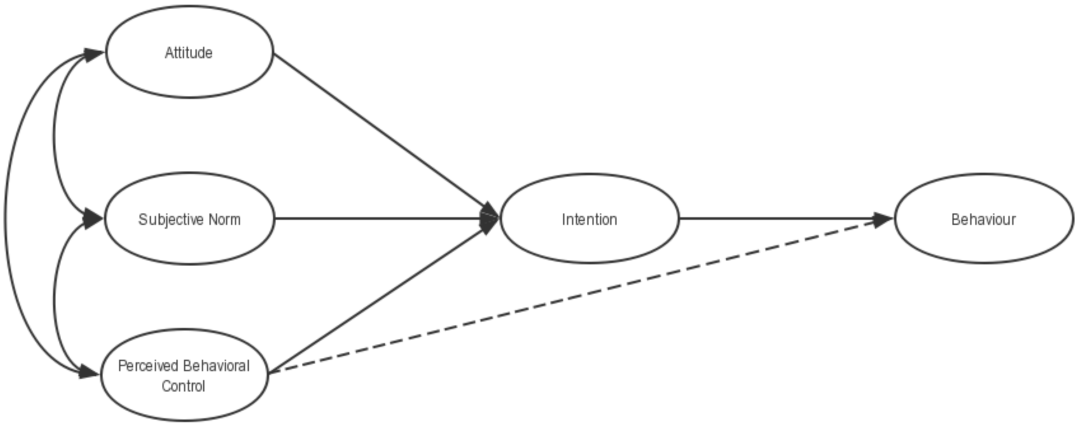



Figure 2.3 Theory of Planned Behaviour and factors influence on intentions and behaviour (Redrawn after: Ajzen, 1985). Solid lines represent a more consistent influence than dotted lines on factors.

The TPB is one of the most prevalent models in the waste management literature to evaluate household recycling behaviour and environmental attitudes. The TRA has been used to model waste separation among teenagers (Barata and Castro, 2013). The TPB has been seldom used for e-waste behavioural modelling with significant results (Le Hoang et al., 2013), compared with household recycling behaviour in general (Table 2.1). Therefore, the decision was made to select from a larger pool of research in waste and resource management in Science Direct studies using the TPB for household recycling behaviour. The goal was to identify which factors were associated with the highest variance explained and then confirm these factors relative to e-waste in subsequent data collection phases (Chapters 4 and 5).

The TPB has been used previously in recycling behaviour and environmental behaviour studies by several other authors (Table 2.1). This has been produced from a selection of existing TPB-based models used for household recycling. Studies used Likert scales to assess behaviour and used statistical confirmatory data analysis. Studies of interest yielding the highest variance explained (Bamberg et al, 2007; Bortoleto et al, 2012; Carrus et al, 2008; De Leuuw, 2014; Perugini and

Bagozzi, 2001; Wan et al, 2014) used Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) to identify the most relevant factors and their relationships.

All 22 studies were selected for using the TPB in waste management related fields, except for Perugini and Bagozzi (2001) and Bamberg (2007) due to the high variance explained their studies demonstrated. No specific countries were excluded, although a majority of the studies are from developed economies. As all studies focused on intentions and some on intentions and behaviour. In the table are presented the authors and date, study location and topic, nature of variables studied, variables having a significant impact on variance and maximum variance explained for intention as well as behaviour when data are available. Studies are ranked in increasing order based on variability explained for intention ($R^2$).

Table 2. 1 TPB-based models for recycling behaviour and environmental attitude TPB-based

| | | | $R^2$ | |
|---|---|---|---|---|
| Authors | Topic | Variables | Intention | Behaviour |
| 1 - Swami et al. (2011) | Household recycling in the UK | Attitude, subjective norm, perceived behavioural control, intention (TPB) + personality traits, individual differences, demographics, Machiavellianism, contentiousness, agreeableness, political cynicism. | 0.22 | 0.22 |
| 2 - Huffman et al. (2014) | Students recycling attitudes | Gender, recycling attitudes, social influence, anthropocentrism orientation, self-reported behaviour. | 0.23 | 0.08 |
| 3 – Vassanadumrongdee et al. (2018) | Behavioural factors for waste management in Bangkok | Attitude, awareness of consequences, past recycling behaviour, perceived convenience, trust, knowledge, demographics (age, gender, marital status, education, household, occupation, income) | 0.25 | N/A |
| 4 - Le Hoang et al. (2013) | E-waste recycling in Vietnam | Attitude, subjective norm, perceived behavioural control, intention (TPB) + recycling habit, interest in economic benefit | 0.27 | N/A |
| 5 - Knussen et al. (2004) | Household recycling in the UK | Attitude, subjective norms, perceived behavioural control, intention (TPB) + past recycling behaviour, perceived habit of recycling, perceived lack of recycling facilities. | 0.29 | N/A |
| 6 - Wan Ab et al. (2012) | Household food waste separation in Malaysia | Attitude, subjective norms, perceived behavioural control, intention (TPB) + demographics (gender, age, employment, education). | 0.33 | 0.09 |
| 7 - Tonglet et al. (2004) | Recycling behaviour in the UK | Attitude, subjective norms, perceived behavioural control, intention (TPB) + pro recycling behaviour, moral norm, situational factors, consequences of recycling, concern for the community, demographics (gender, age, employment, education). | 0.33 | 0.33 |
| 8 - Seacat et al. (2010) | Household recycling | Recycling information, recycling motivation, recycling behavioural skills, kerbside recycling behaviour, demographics (income, employment, education, housing, | 0.36 | 0.36 |
| 9 - Manetti et al. (2004) | Recycling behaviour in Italy | Attitude, subjective norms, perceived behavioural control, intention (TPB) + identity (personal and recycler type). | 0.39 | N/A |

| | | | | |
|---|---|---|---|---|
| 10 - Chan (1998) | Household recycling in Hong Kong | Attitude, subjective norms, perceived behavioural control, intention (TPB) + mass communication. | 0.44 | N/A |
| 11 - Pakpour et al. (2014) | Household waste behaviour in Iran | Attitude, subjective norms, perceived behavioural control, intention (TPB) + moral obligation, self-identity, action planning, past behaviour. | 0.47 | N/A |
| 12 - Kals et al. (1999) | Emotional affinity towards nature | Emotional affinity towards nature, interest in nature, indignation about insufficient nature protection, experience with nature. | 0.47 | N/A |
| 13 - Davies et al. (2002) | Recycling behaviour in the UK | Ascription of responsibility, personal norms, affective evaluation, subjective norms, demographics, attitudes and PBC. (Altruism + TPB) | 0.48 | 0.48 |
| 14 - Bortoleto et al. (2012) | Household waste prevention in the UK | Attitude, subjective norms, perceived behavioural control, intention (TPB) + general environmental attitudes, personal norms, demographics (gender, age, employment, education). | 0.59 | 0.59 |
| 15 – Nduneseokwu et al., (2017) | Formal e-waste collection in Nigeria | Attitude, subjective norms, intention, Environmental knowledge, infrastructure, economic incentive, demographic variables (gender, age, education, income), | 0.62 | N/A |
| 16 - de Leeuw et al. (2015) | High-school students' pro-environmental behaviour | Attitude, subjective norms (injunctive and descriptive), perceived behavioural control, intention (TPB) + individual factors (personality, emotions, intelligence, values, general attitudes, personality traits), demographics (education, age, sex, income, religion, race, ethnicity), societal (social norms, culture, economy, political context). | 0.68 | 0.27 |
| 17 - Barr and Gilg (2005) | Household recycling in the UK | Local waste knowledge, kerbside bin, willingness to recycle, demographics, convenience / effort, awareness of norms to recycle, acceptance of norm to recycle, active concern, importance of nature, house type, knowledge sources, provision. (derived from TRA and environmental behaviour). | 0.68 | 0.46 |
| 18 - Barr (2007) | Household waste management in the UK | Env. knowledge, gender, experience, motivation to respond, group membership, convenience, norm acceptance, citizenship, env. threat, active concern, importance of nature, human priority, kerbside bin. | 0.7 | 0.83 |

| | | | | |
|---|---|---|---|---|
| 19 - Perugini & Bagozzi, (2001) | Body weight regulation in Italy | Attitude, subjective norms, perceived behavioural control, intention (TPB) + anticipated emotions (positive and negative), desires, and past behaviour (frequency and recency) = model goal-directed behaviour (MGB). | 0.76 | 0.3 |
| 20 Carrus et al. (2008) | Household recycling in Italy | Attitude, subjective norms, perceived behavioural control, intention (TPB) + anticipated emotions (positive and negative), desires, and past behaviour (frequency and recency) = model goal-directed behaviour (MGB). | 0.82 | N/A |
| 21 - Wan et al. (2014) | Household recycling in Hong Kong | Attitude, subjective norms, perceived behavioural control, intention (TPB) + consequences, perceived policy effectiveness, moral norms. | 0.84 | 0.88 |
| 22 - Bamberg et al. (2007) | Public transportation in Germany (Dortmund and Frankfurt) | Attitude, subjective norms, perceived behavioural control, intention (TPB) + behaviour, use intention, personal norm, anticipated feelings, problem perception, awareness of negative consequence. | 0.9 | 0.8 |

The TPB has been used in the UK (Davies et al. 2002; Knussen et al., 2004; Tonglet et al., 2004; Barr and Gilg, 2005; Barr, 2007; Swami et al., 2010; Bortoleto, 2012), as well as in other parts of the world, such as Vietnam, Hong Kong, Malaysia, Nigeria, Thailand, or Italy (Chan, 1998; Kals et al., 1999; Perugini and Bagozzi, 2001; Manetti et al., 2004; Bamberg et al., 2007; Carrus et al., 2008; Seacat et al., 2010; Wan Ab et al., 2012; Le Hoang et al. (2013; de Leeuw et al., 2015; Huffman et al., 2014; Pakpour et al., 2014; Wan et al., 2014; Nduneseokwu et al., 2017; Vassanadumrongdee et al., 2018) (Table 2.1).

Although studies differ from country to country and use different statistical methods to compute variance explained, they can be compared and contrasted as the goal is to identify which factors tend to be associated with the highest variance explained. The study with the lowest variance explained for intention is from Swami et al. et al. (2011) with 22% (Figure 2.5). The study which has the lowest variance explained for behaviour with 8% from Huffman et al. (2014). Authors obtained data from both self-reported questionnaires and observations on students' recycling attitudes in the USA. Two of the seldom studies focusing on the TPB and e-waste have done in Vietnam (Le Hoang et al., 2013) with 27% of variance for intention explained and Nigeria (Nduneseokwu et al., 2017) with 62% of intention explained. But none of these studies reported variance explained for behaviour.

In contrast, studies from Bamberg et al. (2007) with 90% of variance for intentions and 80% of behaviour explained on public transportation use and Wan et al. (2014) with 84% and 88% respectively on household recycling in Hong Kong (Figure 2.4). Except Wan et al. (2014), all studies integrated a variable related to emotions or desires. Usually variance explained for behaviour is lower than intentions. This can be partly explained by the difference between declaring a future act and actually realising this act. In other words, the difference between self-reported behaviour and actual behaviour (Corral-Verdugo, 1997). Factors influencing the most variance for intention are perceived behavioural control, perceived policy effectiveness, moral norms, attitude, subjective norms, personal norms and anticipated feelings (Perugini and Bagozzi, 2001, Bamberg et al., 2007; Carrus et al., 2008; Table 2.1). Barr (2007) also obtained significant results but avoided TPB related factors and found that experience, motivation to respond, environmental threat, active concern or experience were significant predictors.

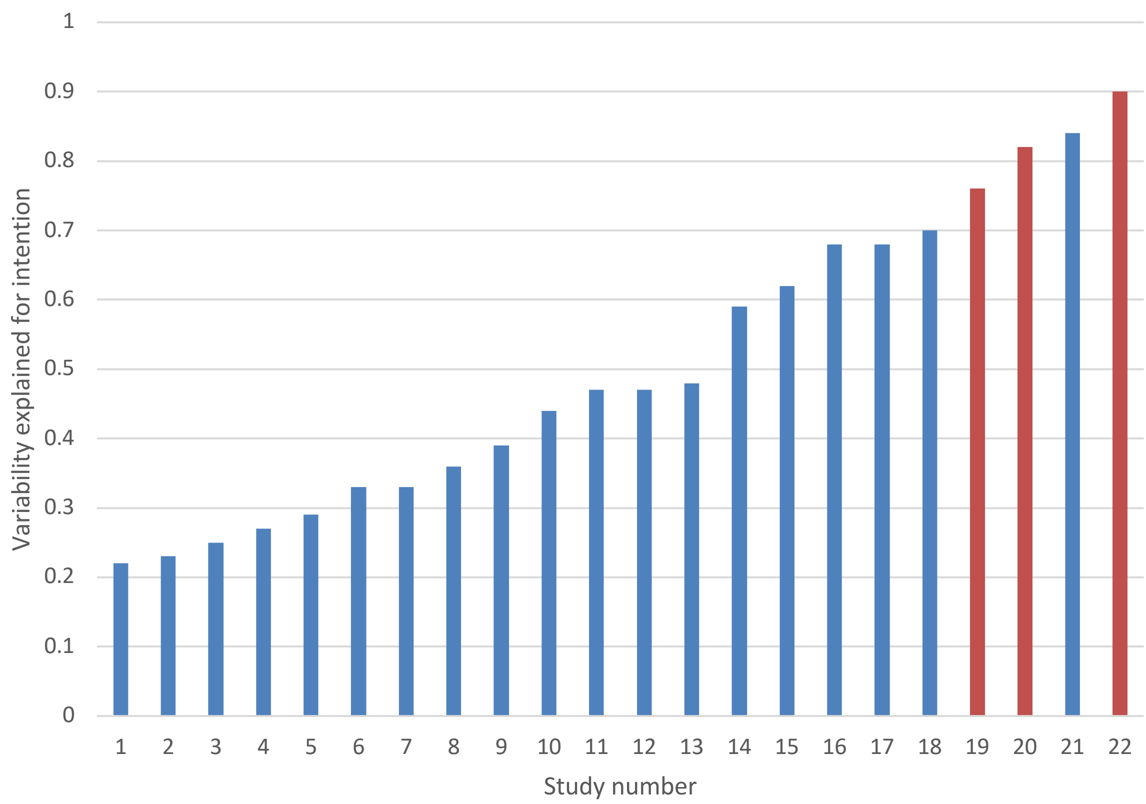



Figure 2.4 Studies ranked in increasing order of variance explained for intention as shown in Table 2.1. Studies integrating emotions in their variables are shown in red

Except TPB-related factors (attitude, subjective norm and perceived behavioural control), additional factors studied vary greatly in nature (Table 2.1). Upon closer review, it is interesting to note that studies with high variance explained tend to include variables related to emotions

Perugini and Bagozzi (2001), feelings (Bamberg et al. (2007), and desires Carrus et al. (2008). Perugini and Bagozzi (2001) derived a new model based on TPB and emotions called the model of goal-directed behaviour (MGB). This model was subsequently adapted by Carrus et al. (2008), with minor alterations, in a study of household recycling behaviour. The MGB used the TPB as the base model and includes anticipated negative as well as positive emotions, prior to engaging in a specific activity (Figure 2.5). Carrus et al. (2008) found that perceived behavioural control, negative anticipated emotions, desires and frequent recycling behaviour were significant predictors of intentions. Their study explained 85% of intentions but variance for behaviour was not reported (Table 2.1). Both Perrugini and Baggozi (2001), and Carrus et al. (2008) studies used self-reported data. All studies have in common TPB and a self-reported pattern, bar a handful with low variances explained. Besides the TPB factors used as a basis among most of the studies, there is not a set of common factors consistently used to increase variance explained.

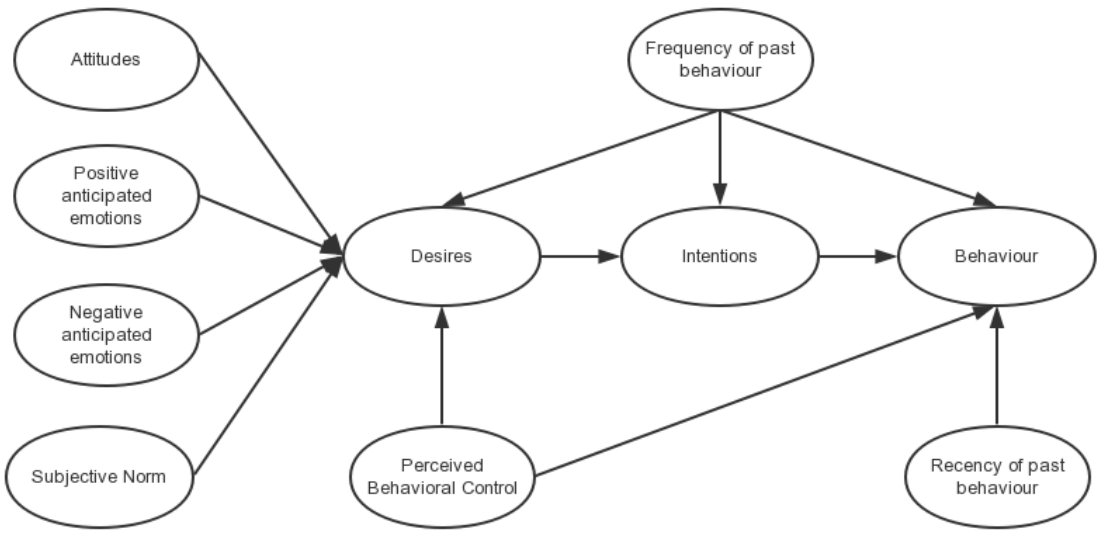



Figure 2.5 The Model of Goal-directed Behaviour (Redrawn after: Pergugini and Bagozzi, 2001)

Barr (2001) worked on predictors of behaviour towards recycling and critiqued the TPB model. He acknowledged the complexity of associations between household attitude and environmental behaviour but aggregated them into three categories rather than one: environmental values, situational variables (personal situation in a behavioural context such as access to static recycling centres), socio-demographics, and individual knowledge. These intrinsic motivations were previously explored by Schwartz (1968) with the notion of Altruism within the Norm Activation Model and with De Young’s (1986) approach to moral rewards. Davies et al. (2002) conducted one of the few studies in the field to measure behaviour with 48% of the variance explained. Davies et al. (2002) used a combination of factors from TPB (Ajzen, 1985) and Altruism (Schwartz, 1968) and have acknowledged the need to investigate how emotions could be further incorporated with these models to improve their predictive power. Davies et al. (2002:10) found the Norm Activation Model from Schwartz (1968) “a more satisfying point for understanding recycling behaviour in affluent industrial societies” compared with the TRA and the TPB. The model is linked to social norms but reinforces the link between intentions and behaviours with the addition of awareness of consequences and ascription of responsibility. One limitation however, is their sample drawn from an affluent area in the UK, the Cotswolds, which is not representative of the larger British population. In their study evaluating the predictive power of TRA, TPB and the altruistic model, Davies et al. (2002) have found the altruistic model more reliable (15%) compared with TPB (9%) or TRA (3%). However, 15% is still insufficient to provide robust predictive factors. Part of their study relies on altruism and the propensity of respondents to have an altruistic behaviour, recycling being perceived as one. However, they identified reward as a driver, whether that be in a morale sense or a monetary sense; households and individuals are seeking a positive effect with recycling, as De Young (1986) had already identified.

These models are useful to "take a snapshot picture" of a current behaviour for specific intrinsic motivators. The TPB forms a robust basis and models including factors associated to emotions tend to have higher variance explained for intention. Although, the results for variance explained for behaviour are inconsistent. To date, the TPB has been used in a handful of studies dedicated to small e-waste end-of-use decision-making. However, before delving deeper into the subject we need to review which methods using extrinsic motivators have been applied to alter e-waste end-of-use behaviour. The aim to use intrinsic and extrinsic motivators is to increase end-of-use small electronics collection rates to exploit existing DUMs. To be exploitable efficiently, DUMs need end-users to behave in such a fashion that it becomes possible to access stockpiles and transform discarding habits into recycling opportunities and stockpiling into reuse decisions. Behaviour change is a complex process that requires the use of various incentives, intrinsic and / or extrinsic in nature (Schultz et al., 1995).

## 2.5 Behaviour change: extrinsic motivators and monetary incentives

Psychological models are useful to understand some elements related to household waste management behaviour, but to exploit DUMs, behaviour needs to be altered at individual level. Extrinsic motivators based on monetary incentives, such as taxes and economic rewards, used to influence behaviour in the waste management field are presented and discussed in this section. Complementary to intrinsic incentives are extrinsic motivators. They can be monetary or non-monetary. Monetary incentives are either defined by penalties such as taxes or by economic rewards (Shaw and Maynard, 2008). Willingness-to-pay (WTP) and pay-as-you-throw (PAYT) studies have demonstrated the difficulties in associating monetary incentives to "waste" (Le Bozec, 2008; Song et al., 2012; Afroz et al., 2013; Yin et al., 2014; Brown and Johnstone, 2014; Zen and Siwar, 2014; Lakhan, 2015). Given the low monetary value of residual materials and their low quantity in mobile devices, incentives are necessarily low and taxes are unpopular by definition, unless they are rebated as a reward. Other studies, mainly in the USA, have investigated consumers' willingness to pay Advanced Recycling Fees (ARF) to finance WEEE collection schemes and develop subsidies to incentive consumers. Nixon and Saphores (2007) found that consumers are willing to pay 1% to finance collection schemes of the item's retail price on average. This amount, however, is insufficient to create a sustainable collection scheme (Nixon and Saphores, 2007). A study in 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). Using a complex system of advanced recycling fees associated and the involvement of local government with subsidies, Bor et al. (2004) suggested the creation of a specific market for these containers by generating new rules to influence the behaviour of producers, consumers, and local government. Whilst the system is laudable, the actual implementation should be demonstrated.

Jones et al. (2010) investigated factors influencing perceptions on WTP based on social capital for household waste, such as social trust, institutional trust, social networks and compliance with social norms. They estimate that approximatively WTP of EUR 0.5 for each waste bag would be acceptable. More specifically adapted to WEEE, Yin et al. (2014) in their mobile phone recycling study in China, estimated that 52% of respondents refused to cover a fraction of recycling costs and 2/3 of respondents who were willing to pay were prepared to pay between up to 5% of recycling costs. The higher the monthly income, the more likely respondents were willing to pay and 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, whilst 11% were willing to pay this fee directly to recyclers (Yin et al. 2014). Song et al. (2012) estimated household average willingness to pay for WEEE recycling in Macau at USD 2.50 per month.

In the UK, Ongondo and Williams (2011) have identified in their research consumers' willingness to increase their WEEE recycling behaviour in response to economic incentives. Even though the existing WEEE legislation offers free TBS, consumers still appear to need to be offered incentives to overcome the associated perceived cost to take back their WEEE (Ongondo and Williams, 2011). However, when WEEE has little or no monetary value left, it is not profitable for collection organisations to offer incentives. In 2003, the average cost in the UK to retrieve a mobile phone in working order to be resold as second-hand on the market was 11 USD (Geyer and Blass, 2009).

Furthermore, if EEE still has some residual monetary value for example when unbroken, consumers can use peer-to-peer (Consumers to Consumers, C2C) websites such as the eBay, Amazon, Gumtree or Schpock marketplaces to resell their unwanted devices. There are also a significant number of for-profit and not-for-profit organisations proposing to buy unwanted mobile and smart phones.

To raise consumers' awareness, monetary incentives to bring back UEEE could be a solution. The main issue is that obsolete EEE has limited residual monetary value (Ongondo & Williams 2011). When there is a significant residual monetary value, consumers might use C2C websites to resell these products. It is perhaps surprising to discover there is little available literature on the topic in the UK. India has implemented such schemes but on a limited scale (Gupta, 2015). There is one paper in China exploring this possibility (Zhong and Zhao, 2012). One report in the USA also explores that possibility and concludes that the focus on Extended Producer Responsibility has left a void in policy-making regarding that aspect (Walls, 2013). But there seems to be no cited study in the EU. On the other hand, Japan and South-Korea have implemented this scheme since the 1990s with apparent success (Herat and Agamuthu, 2012).

Economic incentives attached to WEEE are necessarily very low as monetary value is estimated on materials, not on potential use. The collection pattern is different from general waste as it is necessarily episodic as the quantity of e-waste generated by household is inferior to general waste. Higher monetary incentives for mobile and smart phones exist but for a reuse purpose. If the device is in working order, it still has a monetary value and can be resold with little or no repairs. However, if the device is broken or unusable as is, its estimated value is associated with secondary materials value, which represents only a fraction compared with working devices (Ongondo et al., 2011). If consumers were satisfied of the resale price for their unwanted and unbroken devices, they would use these services more often. But with an estimated 257 million reused units market in 2018 (Deloitte, 2016) compared with more than 2 billion units shipped in 2015 and an average 15% recycling rate in developed economies (Ellen McArthur Foundation, 2015), statistics indicate that many broken and unbroken devices are not being brought back to a collection point.

## 2.6 Behaviour change: extrinsic motivators and non-monetary incentives

Given the low value of economic incentives and sometimes the inefficacy of economic incentives on unwanted working devices, non-monetary incentives could be investigated to offer other alternatives to consumers. They are more varied than monetary incentives in nature and it seems that several non-monetary incentives need to be used in conjunction to achieve significant results. To continue expanding the nature and variety of non-monetary incentives, examples from behavioural economics and choice architecture are presented and discussed below.

Within the waste management field, Timlett and Williams (2008) recommend simple and low cost methods such as public participation in the design of collection methods to increase recycling performance. Keramitsoglou and Tsagakaris (2013) prefer the term "empowerment". Stromberg et al. (2015) support trials to durably change behaviour. Chan (1998) and Read (1999) advocate communication campaigns. There is a shift towards more personalised messages (Tompson et al., 2015) to alter durably behaviour. This approach is nowadays cost-effectively possible with social media and interest groups (Caniato et al., 2014). Werner (2003) underlines the importance of integrating social and physical contexts when attempting to enhance intrinsic motivators. Messages, raising awareness, engaging with local communities are regularly used to increase WEEE collection rates. But other factors could be explored to attempt improving variance explained for intention and behaviour.

Behavioural scientists have long investigated the effects of emotions and perceptions on judgment. Tversky and Kahneman (1992) have associated the concept of "utility" with ownership. They have demonstrated that owning a product distorts market valuations: if one owns a product, one will tend to overvalue its monetary value, compared with its actual market value.

Therefore, whilst behavioural models derived from psychology have been used to understand household recycling behaviour, techniques from behavioural economics could be adapted to increase small WEEE collection rates, especially for mobile and smart phones which are ubiquitous and under-collected. Mobile and smart phones end-of-use barriers could be better understood, reduced and prevented by using Behavioural Economics concepts. The works of Tversky and Kahneman (1992) on users' endowment effect and Thaler and Sunstein (2008) on Choice Architecture could be associated and applied to mobile and smart phones end-of-use decisions to improve outcomes and increase collection rates.

## 2.7 Behavioural Economics: The Endowment Effect

The "Endowment Effect" (EE) is the overvaluation of owned objects compared with the object's actual market valuation (Thaler, 1980). "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 EE is influenced by factors such as "status quo bias" (Samuelson and Zeckhauser, 1988) "loss aversion" (Kahneman and Tversky, 1984) experienced by owners when they foresee parting from a possession. Status quo bias is illustrated when an owner takes a decision leading to non-action i.e. an individual tends to remain in a known situation rather than making a decision with an uncertain outcome as "the disadvantages of leaving it loom larger than advantages" (Tversky and Kahneman, 1991:198). Loss aversion is the anticipation of a potential future loss. When one foresees parting from an owned object, one projects the situation without the object and associates emotions. If these emotions are negative due to missing the object, one is averse to these negative emotions and is consequently unfavourable to the object loss. Losses equivalent to gains are perceived as more painful than the potential positive emotion associated with a symmetrical gain (Kahneman and Tversky, 1984). For example, a loss of $100 represents more negative emotion than the positive sensation for a $100 gain. The EE is associated with the pain felt when an owner contemplates parting from an owned object (Tversky and Kahneman, 1991). To alleviate the potential pain, individuals tend to overvalue an object they own to enter in a transaction. For example, according to the Endowment Effect, someone who has just acquired a brand-new smartphone, if asked to part from it immediately, they would ask for more than the device market value. This price increase would be justified to overcome the loss of an object that has been desired and the time spent to acquire it.

In addition to loss aversion and status quo bias, other factors have an influence on the EE, such as time and emotional affect. The EE has been demonstrated as immediate by Kahneman et al. (1990). Individuals experience loss aversion even a few moments after an object has been acquired by a new owner and hence tend to prefer the status quo rather than trading their good. Strahilevitz and Loewenstein, (1998) have demonstrated that the longer the ownership of an object, the stronger the EE. They call these phenomena the "duration-of-current-ownership effect" and the "duration-of-prior-ownership" effect (Strahilevitz and Loewenstein, 1998:285). The first effect refers to the association of time and ownership. The second effect refers to lost property and the longer it was owned, the more emotionally painful the loss. The influence of time may be explained by the sentimental attachment one might have for an object (Kahneman et al., 1990). On the other hand, strong negative emotions have opposite influences on the EE; researchers such as Lerner et al. (2004) have shown that disgust actually cancels the EE and that sadness can reverse it.

However, further research on the EE has demonstrated limitations of the concept. Morewedge et al. (2009) disagree that loss aversion creates the EE and argue that ownership is a better predictor. In their experiment, professionals who made a living trading goods such as brokers did not express the EE, as opposed to owners who acquire an object for personal purposes. Dommer and

Swaminathan (2013) discarded the EE and suggested that the positive feeling associated to possessing an object is more relevant than the negative emotion associated to parting from it. Nevertheless, all studies acknowledge factors influencing individuals' perception on monetary valuations.

## 2.8 Behavioural Economics: Choice architecture

Thaler and Sunstein (2008) have developed the concept of "choice architecture". This concept connects with the notion of routines to complete sets of tasks, such as eating habits, work habits, or end-of-use habits in the present study. They argue that if individuals were perfectly rational, they would set their default routines to achieve anticipated outcomes, such as engaging in a healthy life-style or saving regularly for the future. They demonstrate that habits and routines overcome these rational outcomes. To help individuals making the "right" decisions, they suggest the design of specific alternatives set as default options. Users would then use these default options and start creating new routines. Adapting choice architecture theory to end of use decisions for mobile and smart phones, could improve end of use decision-making by creating default options that would prevent from stockpiling and discarding.

Researchers such as Iyengar and Lepper (2000) have postulated that too many choices for common decisions are not helpful to everyday decision-makers. This may be because too many alternatives are confusing and require too much cognitive effort for simple recurring decisions. Tversky and Kahneman
(1974) argued that humans use heuristics to approximate complex situations and make rapid decisions. Decision-makers tend to evaluate alternatives based on their past experiences, emotions, state-of-mind and other affective biases. Thaler (1980) claimed that choices should be designed as per expected outcomes for the benefit of the decision-maker. Thaler et al. (2014:429) coined the term "choice architecture" and described a choice architect as the person "who has the responsibility to organise the context in which people make decisions." They agree with Tversky and Kahneman (1974) that humans tend to make decisions based on emotions and previous experiences rather than acting as pure rational decision-makers with abilities to constantly rationalise all decisions made. Choice architects are like designers, who reflect on the purpose of objects and design them as per their intended use. A good design should intuitively lead a lay person to make good use of an object without having to be inducted. For example, products made by the company Apple are known for the quality of its hardware and software designs and the relationship it is able to create with its users through its products (The Economist, 2016). Choice architects act in a similar manner by focusing on intangible decisions by associating

default options (Thaler et al., 2014). Among several alternatives, the influence choices by creating default options towards the most desired outcome.

Thaler et al. (2014) recommended using choice architecture to help consumers to make better decisions for themselves without necessarily noticing that this decision was framed. The aim of choice architecture is to set defaults as per the intended aims. Consumers can opt-out but Thaler et al. (2008) have showed that consumers rarely move away from the default option. They give examples in health-care or retirement saving plans where the default option is set to select the best value for health-care coverage or optimise the amount to be saved regularly for future retirement. To go further than defaults and to engage consumers on a decision path, Thaler et al. (2008) “nudging” consumers. Nudging consumers can be associated to orienting their decision-making process towards a favoured outcome, as suggested in the health-care example above. To create defaults options and nudge consumers, Thaler and Sunstein (2008) have used the NUDGES acronym to structure the approach one should have when designing choice architecture: iNcentives, Understand mappings, use Defaults, Give feedback, Expert error and Structure complex choices into manageable sub-choices (NUDGES). Johnson et al. (2012:489) draw on Thaler and Sunstein (2008) to propose 11 tools for choice architecture:

- reduce the number of alternatives
- use technology for decision aids
- use defaults
- focus on satisfying
- create limited time windows
- set the decision process in stages
- partition options
- limit the number of attributes
- translate information for better “evaluability”
- customise information as per the decision-maker profile
- focus on experience.

These recommendations outlined by Thaler and Sunstein (2008) and Jonhson et al. (2012:489) are not set in stone and can be adapted to different situations. Gigerenzer (2002) expresses the idea of a modular toolbox, where the choice architect can take any technique that might be suitable to achieve a desired outcome. Choice architecture is also referred to libertarian paternalism by Thaler and Sunstein (2003). This apparent contradiction is justified by the decisions set by policy (paternalism) but decision-makers remain free to opt out (libertarian). This has been described as: “an approach that preserves freedom of choice but that authorises both private and public institutions to steer people in directions that will promote their welfare” (Thaler and Sustein, 2003:179). Mitchell (2005) recognises the power of defaults but argues that this approach is benevolent; he is wary that central planners could have too much power influencing individuals, and argues that defaults would not be set in favour of individuals but rather in the interests of policy-makers. Smith et al. (2013:159) question the ethical implications of “choice without awareness”. Instead of placing the decision-maker in a passive decision-making framework, they recommend the use of “smart defaults” to make “active choices”. Smart defaults are the proposition of options in real-time according to consumer preferences. These live updates are suitable for online settings. For example, when consumers are shopping online, they select a set of criteria and a series of products / options are presented. Smith et al. (2013) show evidence that smart defaults are now a staple of online shopping experiences. The authors suggest that they should become the norm when consumers make more important decisions for their future, for example in terms of health care and pensions, especially as these decisions can now be made online with access to large amounts of information.

In 2010 in the UK, choice architecture gained public attention when the British government set the Behavioural Insights Team (BIT) (The Behavioural Insights Team, 2017). Their work aimed to reduce policy production by offering nudges. Through partnerships with various public bodies such as the Department of Health (to increase organ donation by testing message framing) or HM Treasury (to reduce poverty by setting a decision-making framework aimed at enhancing household economic decisions). As Behavioural Economics and Choice Architecture become more widely accepted by public bodies and organisations, examples have been found in the field of waste / resource management. Baxter and Gram-Hanssen (2016:100) have applied NUDGES to environmental messaging. They argue that messages aimed at promoting mobile phone recycling should move away from promoting benefits, as this has limited impact on consumer decisions, but rather focus on focus on the detrimental effects of “do nothing” and the negative environmental consequences. This approach connects with the creation of guilt and negative emotions, supposed to trigger an intended behaviour. This may be an over-simplification and may only explore a subset of the "adaptive toolbox formulated by Gigerenzer (2002).
The Choice Architecture trend is growing but it has not yet been applied for small e-waste. Current small electronics end-of-use decisions have not been framed within a choice architecture intention. WEEE collection solutions offered to users are presently unsatisfactory and they would rather stockpile or discard UEEE (Ongondo and Williams, 2011). Individuals choose to hold on to their electronic devices if there is no valid alternative available, despite the legislation in place and the take-back schemes offered by retailers. If the device has some monetary value left (Ongondo and Williams, 2011), and the market valuation of the device meets households’ expectations, then

the device will be sold. If this is not the case, it will be stockpiled. It seems thus clear that stockpiling behaviour is not a rational economic decision as the household utility for the devices will continue to decrease over time, and the longer the WEEE is stockpiled the more likely it is to end up in the general refuse (Gutierrez et al. 2010).
On the other hand, a choice architecture toolbox (Gigerenzer, 2002) for small high-end electronics could be implemented to good effect. For example, it may be possible to counter the trend of stockpiling mobile electronic devices by offering better end-of-use alternatives to consumers when reaching this decision point. Barr et al. (2013:68) outline that NUDGES and social marketing are effective methods to promote recycling. But they explain that these methods need to be correlated with efforts to promote reuse and repair, as end-of-use decision formulations are made in a complex decision-making environment involving many possible alternatives. Consequently, NUDGES and other choice architecture techniques should be adapted simultaneously to the entire pallet of end-of-use decisions: reusing, reselling, recycling and discarding.

## 2.9 Research needs and priorities

Behaviour change is a complex process which requires constraints and incentives from various horizons. WEEE legislation has been influential for large WEEE collection rates but less so for small WEEE (§2.1; §2.2). Urban Mining and DUM exploitation could be improved if individual behaviour was influenced to increase collection rates (§2.3). Intrinsic motivators and behavioural models represent part of the end-of-use decision-making process (§2.4). Extrinsic motivators are represented by monetary incentives and are exemplified by schemes offering cash for unwanted mobile and smart phones in working order (§2.5). Behavioural Economics show the influence of intrinsic motivators on extrinsic motivators, such as the Endowment Effect on an object subjective valuation (§2.6). To date, no model has been successfully developed to explain fully small e-waste end-of-use decisions. The endowment effect has not yet been demonstrated for small electronics. Monetary incentives seem insufficient to entice consumers to part from their mobile or smartphones, but non-monetary incentives are not being investigated. There is currently limited research on non-monetary incentives designed specifically to counter small electronics stockpiling behaviour. Choice architecture could be used to associate monetary and non-monetary incentives with existing collection systems to improve small electronics collection and reuse rates. To attempt bridging this research gap, an exploratory mixed methods data collection was developed to investigate end-of-use behavioural factors relative to small electronics.

## 2.10 Research aims and objectives

Overarching aim: To elucidate behavioural factors influencing the storage of small electronic devices, using mobile and smart phones among young adults as a case study.

Aim 1: To evaluate and analyse critically current behavioural models associated with end-of-use decision-making regarding mobile and smart phones **-> Chapter 2**
Objective 1: To analyse end-of-use behavioural models from the waste and resource management literature
Objective 2: To critically appraise key factors involved in these behavioural models

Aim 2: To identify and evaluate critically factors associated with end-of-use decision-making regarding mobile and smart phones **-> Chapter 4**
Objective 3: To use waste and resource management expert knowledge to select factors associated with end-of-use decisions
Objective 4: To critically analyse factors selected by Delphi panel members

Aim 3: To propose a theoretical model specific to end-of-use decision-making regarding mobile and smart phones**-> Chapter 5**
Objective 5: To confirm prominent behavioural factors associated to end-of-use decision-making
Objective 6: To measure the influence of behavioural factors on end-of-use decisions
Objective 7: To define stockpiling and hoarding decisions

Aim 4: To critically discuss the influence of behavioural factors on the hoarding decisions of mobile and smart phones**-> Chapter 6**
Objective 8: To design a framework based on the Theory of Planned Behaviour to recognise and prevent hoarding
Objective 9: To propose a method using Choice Architecture to exploit Distinct Urban Mines

# Chapter 3: Research Design

This chapter outlines and explains the research design adopted to achieve the aims and objectives of the thesis. It also discusses issues relating to reliability and validity and outlines how these were addressed.

## 3.1 Overall research design

This methodology follows an exploratory mixed methods approach (Plano Clark et al., 2008). A thorough literature review of existing household recycling factors was undertaken, as well as factors stemming from behavioural economics. Then, a qualitative phase to explore factors precedes a quantitative phase to quantify factors and generalise findings.

The factors identified in the literature review (Table 2.1) were submitted to a panel of waste and resource management practitioners to determine which ones would be the most relevant. The selected factors were subsequently appraised with a social survey over a large random sample (quantitative phase).

A mixed methods approach is often used in social science (Mertens and Hesse-Biber, 2012) and has also been applied to waste management (e.g. Yoada et al, 2014; Manzi, 2015; Udawatta et al., 2015; Mozo-Reyes et al., 2016). Mixed methods imply a combination of quantitative and qualitative data collections. This association of opposite worldviews (positivism with quantitative data collection and constructivism with qualitative data collection) has been developed since the early 1980s (Morgan, 2007), leading to a new research paradigm known as pragmatism (Creswell and Plano Clark, 2007).

Mixing data collections can be carried out in sequential order or concurrently (Johnson and Onwuegbuzie, 2004). Sequential order is either exploratory, with qualitative data collection first, or explanatory, with qualitative data collection used to enhance the results from the quantitative phase. Concurrent data collection is either embedded or triangulated. In an embedded design, two types of data are collected to answer two distinct questions within a single study (Kwok, 2012). In a triangulated design, the results are used to enhance the validity of the results (Mertens and Hesse-Biber, 2012). Also the pre-eminence of qualitative analysis or quantitative analysis will determine which research paradigm will prevail, either constructivism or positivism (Johnson and Onwuegbuzie, 2004).

## 3.2 Exploratory mixed methods

Exploratory research designs are used to identify variables that will be tested in a quantitative phase (Archibald et al., 2015). This approach requires the identification of a body of knowledge to identify variables that will be qualitatively and iteratively evaluated (Hesse-Biber and Johnson, 2015). Variables of interest will be extracted and subsequently generalised in a quantitative phase with a sample of university students. Exploratory research overcomes the limitations relative to qualitative or quantitative designs and associates the strengths of both methods (Johnson and Onwuegbuzie, 2004). Qualitative data collection is useful for describing complex phenomena but information generated is difficult to generalise (Plano Clark et al., 2007). On the other hand, quantitative data collection can be used to generalise findings (Collins et al., 2007). However, relevant variables need to be identified in the first place (Kwok, 2012). Mixed methods attempt to overcome limitations associated with the isolated use of qualitative and quantitative data collection procedures. Still, some limitations are inherent to mixed methods designs (Johnson and Onwuegbuzie, 2004). It might be difficult for a single researcher to conduct all data collection phases without the support of a research team. The research team needs to master several data collection and analysis methods. Successful mixed methods require adequate data collection methods associated to relevant technology (Hesse-Biber and Johnson, 2015).

### 3.2.1 Qualitative data collection

Qualitative data can be accurately generated with Delphi methods (Hsu and Sanford, 2007). The Delphi method comprises a consensus-building process developed for the Research And Development (RAND) Corporation in California, USA by Dalkey and Helmer (1963) designed to elicit expert opinion. Several waste management studies have used this method (e.g. Bouzon et al., 2016; Curzon and Kontolen, 2016; Lehtonen and Tykkylainen, 2014; Zangenehmadar and Moselhi, 2016), but only three specifically with WEEE (Kim et al., 2013; Raut et al., 2016; Cruz-Sotelo et al., 2017). Panel members are invited to take part in a data collection process involving at least two rounds. Rounds are used to create consensus iteratively. Data can be collected via interviews, open or semi-open questions including Likert scales and / or semantic differentials to rank factors (Hsu and Sanford, 2007). To avoid groupthink and potential influences in responses panels are not aware of other members’ presence (Landeta et al., 2011). 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 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). One major 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 circumvent this problem.

Online questionnaires are regularly used to gather expert opinion in a Delphi setting (e.g. Gijsbers et al., 2016; See-To et al., 2016; Steinert, 2009; Yeh and 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 data analysis, reduces errors and expands the geographic origins of respondents by removing physical barriers (Bloor et al., 2015). However, online Delphi, sometimes also called e-Delphi, has limitations (Donohoe et al., 2011). Some panel members might not have access to the Internet, although inviting panel members via e-mail prevents this issue. Hardware or web-based survey tools could fail and data could be lost. Data collection needs to be scheduled within appropriate time frames as it would be done for a physical, onsite data collection event. In addition, it is difficult to ensure invited respondents are the ones completing the questionnaire, but this can be mitigated by sending individualised links to respondents. Web-based methods attenuate time consuming issues associated to traditional Delphi methods and, if appropriately selected and designed, could enrich the value of the data collected by using innovative methods associated to decision science.

### 3.2.2 Quantitative data collection

Following a qualitative phase based on Delphi data collection procedures, a quantitative phase is required to finalise the exploratory methodology (Johnson and Onwuegbuzie, 2004). This data collection stage enables probability sampling, external validity and representativeness to a population (Lieber, 2009). In a sequential mixed methods approach, this phase opens the possibility to generalise the qualitative results obtained in previous phases (Hesse-Biber and Johnson, 2015), if the sample is large enough and representative of the studied population. To that purpose, the 10-step “Instrument Development of Construct Validation” (IDVC) framework from Onwuegbuzie et al. (2010) has been adapted for the present study as follows.

Conceptualise the construct of interest:

1. Identify factors of interest for the construct from the literature
2. Develop initial qualitative instrument, pilot-test and design Delphi data collection rounds
3. Field-test revised instrument with Delphi panel members
4. Validate factors identified by panel members
5. Transfer identified factors into the quantitative data collection framework
6. Develop initial quantitative instrument, pilot-test and design quantitative data collection
7. Field-test revised quantitative instruments with sample
8. Analyse and generalise results
9. Construct framework

This framework has been used to structure the data collection process for qualitative and quantitative phases. It was then used to develop a framework representing an improved end-of-use decision-making process for small electronics, using mobile and smart phones as a case study.

## 3.3 Reliability and validity

Reliability is the capability of an instrument to obtain consistently similar results over time. Validity is the capacity of instrument to measure what is intended to be measured. This section describes how these issues were addressed in this study for both qualitative and quantitative phases.

### 3.3.1 Inter-observer reliability

Inter-observer reliability evaluates observers' consistency in their observations. In other words, how reliable is their judgment for the same construct (Litwin, 1995). This is assessed by correlating scores or judgements between observers. Whilst this test is valid to identify inconsistencies (De Vaus, 2002), it is not adapted for Delphi studies. Differences in expert judgement are sought to establish consensus. Similarly, for a quantitative phase, respondents may be asked to share their experience(s) on their own mobile and smart phone usage.

### 3.3.2 Test-retest reliability

Test-retest reliability evaluates the temporal stability of the construct (Field, 2005). The same questions are administered to the same sample at different points in time. High correlation levels indicate that the questions are reliable. However, this time factor also induces limitations (De Vaus, 2002). If the time between the assessments is too short, a memory effect could influence correlation. Similarly, if the time interval is too long, “maturation” (Gideon, 2012) might affect results. Maturation refers to the changes of a subject over time. This a possibility for longitudinal studies seeking input from respondents over a long period of time. This evolution in perceptions might influence responses to the same questions. This study being cross-sectional, the test-retest was deemed inapplicable. First, test-retest procedures might lower respondents’ willingness to engage in data collection methods. Similarly, data reliability might be affected due to respondents’ “tiredness” to re-answer the same questions. Then, the large Delphi sample and the aggregation of results lowers reliability issues. This is also the case for the quantitative phase where results have been aggregated.

### 3.3.3 Parallel-forms reliability

Parallel-forms reliability requires different measures from the same sample at different points in time (Litwin, 1995). This test only slightly differs from the test-retest for reliability. The difference lies in the wording used for the questions. Therefore, if respondents have similar responses over the two instances, the test is deemed conclusive. Similarly to the test-retest approach, memory and maturation could affect results and invalidate the test. Also, for the same reasons presented before (§3.3.2), there was no need to submit respondents to a similar type of questions as it might reduce respondents’ willingness to engage and affect overall results.

### 3.3.4 Internal consistency reliability

Internal consistency reliability gauges how appropriately a test measures what it is intended to measure (Black, 1999). It is expressed with Cronbach’s alpha which measures the homogeneity of a construct. In other words, how reliable are the results. The same construct is divided in equal segments and responses should be homogeneous in each segment, illustrated by a high Cronbach’s alpha value. The theoretical value of Cronbach’s alpha varies from 0 to 1. This is because it is the ratio of two variances and the variance in the denominator is always at least as large as the variance in the numerator. Values superior to 0.7 indicate robust and reliable results. This test will be conducted for both qualitative and quantitative phases for data collected with Likert scales.

### 3.3.5 Face validity

Face validity is a subjective judgment on accuracy of construct (Gideon, 2012). In other words, it estimates if the instruments used for data collection are measuring what they are supposed to measure. To conduct the test, respondents read through the different questions and deem if the questions are valid with the intended purpose (Litwin, 1995). This test is easy to realise but is considered weak as it relies on subjective judgment. To limit this issue, several respondents should be asked to conduct a face validity. Hardesty and Bearden (2004:99), report that at least three "judges" should conduct a face validity. The plurality of judgments reduces subjective limitations. Therefore, ten academics and non-academics from and outside the waste and resource management field were contacted to conduct this test for both data collection rounds.

### 3.3.6 Content validity

Content validity is a subjective measure of the domain representability to the wider studied domain (De Vaus, 2002). This test aims to answer the question: "Within the defined field of study, are the indicators valid for the study?" To counter the limitations associated with subjective judgment, several viewpoints are necessary. As with the face validity test (§3.3.5), several practitioners and non-practitioners were asked to assess the content validity prior to proceeding with the qualitative and quantitative data collections.

### 3.3.7 Criterion validity

Criterion validity measures if the findings from the investigated set of measures are similar to the measures from the wider studied concept (Litwin, 1995). A high correlation level is desired to establish the validity of the studied criteria. However, in exploratory methodology, this measure is inadequate since new measures need to be established. To counter this issue, a thorough literature review was conducted to extract relevant measures that should be investigated during the qualitative phase. Then, Delphi panel members selected the most important variables that were then fed into the social survey for the quantitative phase. This iterative method ensures that criteria identified are valid.

### 3.3.8 Construct validity

Construct validity is used to assess how well the measure conforms with theoretical expectations (De Vaus, 2002). This test is valid when established theoretical frameworks are used to investigate measures, such as the Theory of Planned Behaviour (Ajzen, 1985). However, in this study no single theoretical concept was used to investigate mobile and smart phones end of use decisions. On the contrary, several concepts were borrowed from various theoretical backgrounds associated to waste management and behavioural economics (Table 4.1).

### 3.3.9 Threats to reliability and validity and how they were minimized

To address these threats, the following approach was made for qualitative and quantitative phases (Table 3.1). Both qualitative and quantitative phases were piloted before being released.

For the qualitative phase, a purposeful sampling was undertaken by using the contacts from the supervisory team. Maturation was not an issue in the qualitative phase as there was a three-month gap between both rounds. Measure instruments were first validated by Delphi panel members and then transferred onto a quantitative survey disseminated to students following the University of Southampton's code of ethics.

For the quantitative phase, care was taken to assemble a random sample by spreading the survey invitation on various media, such as university portals, course portals and Facebook groups (§5.2.3). Data were collected at the same time over two different campuses.

Table 3.1 Threats to survey reliability and validity (Black, 1999 and De Vaus, 2002) and responses to mitigate these issues

| Common threats | Responses to threats |
|---|---|
| Non-representative sample | Random sample among university students from 2 different UK campuses |
| Maturation | For the qualitative phase: 3 months between each round). For the quantitative phase: a single data collection over a two-week period with the possibility to interrupt and resume the survey |
| Inadapted measure instruments | Qualitative phase used to identify relevant variables for the quantitative phase. Quantitative phase used categorical data for demographics, ordinal data for respondents' preferences and continuous data for monetary valuations |
| Inappropriate use of instruments | Instruments used to identify and measure behavioural factors related to small electronics end-of-use decision-making |
| Vague wording | Both surveys were pilot tested and terms that might have not been clearly understood were linked to dictionary definitions and the term "utility" replaced by the "usefulness" to avoid any ambiguity during the social survey. |
| Inaccurate coding | Coding was used in the qualitative phase and care was taken to translate the variables used in the Delphi phase into relevant concepts (Table 4.5, Appendix N) |

### 3.3.10 Experimental design

Following this exploratory mixed methods methodology (Plano Clark et al., 2008; Figure 3.1), qualitative primary data were collected and analysed (Chapter 4) to inform the design of the subsequent quantitative phase (Chapter 5). Finally, with a focus on quantitative results to generalise the study implications and applications, results from both Chapter 4 and 5 were interpreted (Chapter 6).

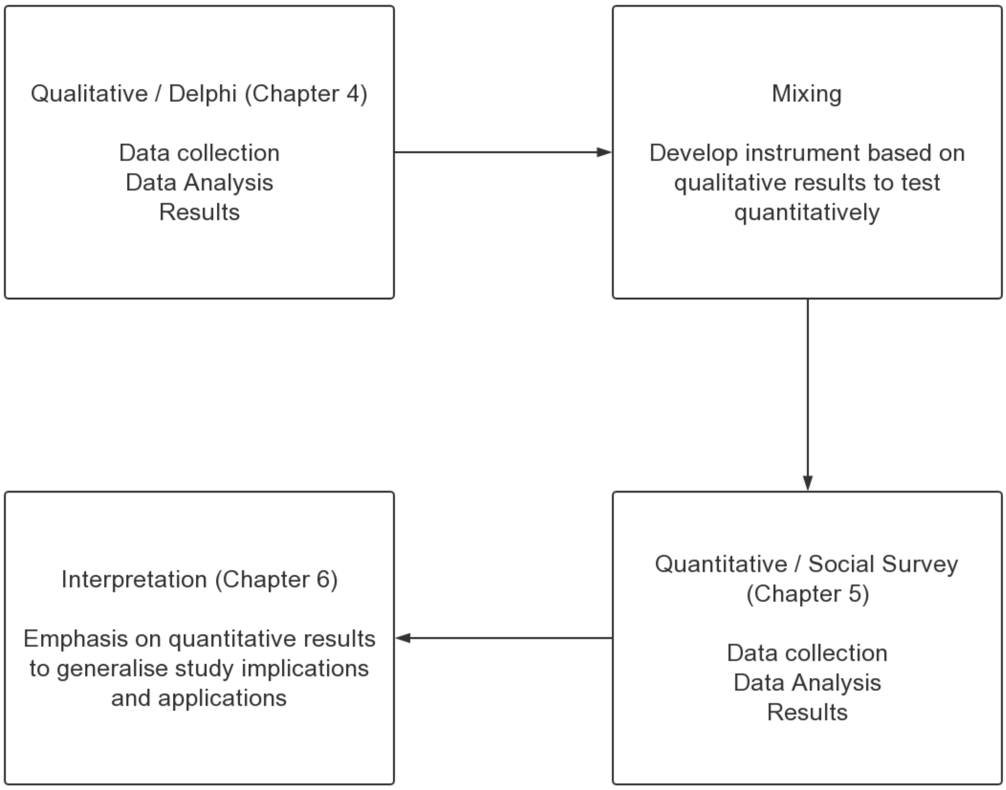



Figure 3.1 Exploratory mixed methods experimental design (adapted from Plano Clark et al., 2008)

### 3.3.11 Next chapters overview

This chapter has presented the data collection plan and the how it would address challenges inherent to the research methods. The qualitative data stemming from the Delphi study are presented in Chapter 4. Then, Chapter 5 reports on the quantitative phase. Both chapters present in more details their research methods and findings are discussed with the literature, Finally, Chapter 6 attempts bringing together the critical analysis performed in Chapters 4 and 5 to develop recommendations for waste and resource management practitioners. Chapter 7 concludes by showing that the study aims and objectives have been achieved, as well as the original/notable contributions of this overall research programme.

# Chapter 4: Using Delphi Methods to Explore End-of-use Behaviour for Mobile and Smart Phones

This chapter presents the main qualitative data collection aspects of this study (§3.2.1). The aim was to identify and critically evaluate factors associated with end-of-use decision-making regarding mobile and smart phones to select factors associated with end-of-use decisions, by critically analysing factors selected by Delphi panel members.

Using Delphi methods (§4.2.1; §4.2.2; §4.2.3), a carefully selected panel of mostly Western European Waste Management members (§4.2.4) was consulted to select which factors were deemed the most important among the waste management and behavioural economics literature (§4.2.5). These factors were then used to inform the subsequent quantitative data collection phase of this study (Chapter 5).

## 4.1 Methods

### 4.1.1 Delphi methods justification

Using the Delphi method as a pre-phase to quantitative data collection is favourable as the method explores an area before quantifying its results (Fletcher and Marchildon, 2014). To collect qualitative data, a Delphi consultation was organised among Waste Management Practitioners from Western Europe using convenience sampling (Hedt and Pagano, 2011; Emerson, 2015) between June and September 2015 (§4.2.4). The aim was to select factors from the waste management and behavioural literature review economics literature review (Table 2.1) by achieving two objectives; filtering down the number of factors using a threshold value and measuring end-of-use alternatives importance in the end-of-use decision-making process: sell, reuse, recycle and discard.

The Delphi method is regularly used by waste management researchers to enhance the data collection process (Joshi et al., 2011; Tang et al., 2014; Sekhar et al., 2015; Bouzon et al., 2016; Delbari et al., 2016), as well as for e-waste (Kim et al., 2013; Raut et al., 2016; Cruz-Sotelo et al., 2017). There are advantages and disadvantages to the use of Delphi methods over selecting focus groups (Landeta et al., 2010). One main advantage is the consultation of participants associated with the field of research (Hsu and Sandford, 2007). Organising focus groups would have required participants to be present at a specific point in time and given location. This would have limited the potential number of participants. The online methods allowed an asynchronous participation maximising the potential number of participants and minimising the amount of time they would dedicate to the data collection (Donohoe et al., 2012). Using Delphi among mostly Western Europe waste management academics and professionals would allow a broad panel and this breadth would reinforce the results robustness. Given the fact that the quantitative data collection phase would be carried out within the UK, it could have been more convenient to only invite waste management panel members from the UK. However, by targeting the panel composition in this fashion, this would have limited the number of participants and would likely have produced less robust results than with a panel with as many participants as possible. Another possibility would have been focus groups among students on university campuses (Onwuegbuzie et al., 2010; Landeta et al., 2011; Fletcher and Marchidon, 2014), considering the quantitative data collection would be done on university campuses. Although their physical participation would have been uncertain, it was decided to reserve students' participation for the later quantitative data collection phase administered online.

#### 4.1.2 Delphi methods

Delphi data collection was created by the Rand Corporation (Dalkey and Helmer, 1963). Its aim is to aggregate panel members' knowledge and minimise bias among panel members, i.e. "groupthink" (§3.2.1). The system requires participants' anonymity among themselves and at least two rounds. Data from all participants gathered during the first round are compiled and then presented back to participants in a second round (Hsu and Sandford, 2007). Participants are then required to analyse the data from round one and provide additional insights. The process is continued until a consensus is reached, which may in some instances require more than two rounds. In this study, it was decided (1) to limit the data collection to two rounds as each round related to a specific objective and (2) to avoid participants' reluctance to engage in a protracted process.

#### 4.1.3 e-Delphi or online Delphi

The Delphi rounds were administered online using Survey Monkey for round one and PAPRIKA for round two. More information is presented on these data collection methods in section 4.2.5. There are several advantages administering a Delphi survey online as opposed to physically (§3.2.1). One advantage is the possibility to gather panel data in an asynchronous fashion, therefore removing the limitations posed by the necessity to have panel members present in the same location at the same time. An asynchronous physical Delphi could be organised but this would require the data collector to travel to several locations and arranging in advance meetings with panel members. This would lengthen the data collection process, increase data collection costs and could reduce the number of potential participants. A disadvantage of the online method is the requirement of participants to have Internet access and ensuring the data collection process is clearly explained to ensure that data collected are valid (Donohoe et al., 2012). The Internet limiting factor is unlikely in Western Europe and this would add a positive qualifier for panel members as the study focuses on mobile and smart phones. To ensure data collected would be valid, both rounds were piloted among academic and PhD researcher colleagues, ten participants for round one and five for round two.

Data collection occurred in June 2015 for round one and September 2015 for round two, after ethical approval was obtained (Appendix A). Participants were given four weeks to complete each round and a reminder was sent after two weeks.

#### 4.1.4 Panel members

Delphi participants were selected from the research team contacts using convenience sampling (§4.2.1), composing an intended sample of 205 participants. This data collection method is relevant as the research team has created a vast breadth of contacts within the waste and resources management field in Europe and more specifically in Western Europe during conferences and joint research projects. Typically, the intended panellists were affiliated to governmental organisations dedicated to waste management, private organisations specialising in recycling, waste management from local councils or academics from the waste and resource management field.

An intended sample of 205 participants was contacted. To be valid, a Delphi data collection requires at least ten panel members (Hsu and Sanford, 2007). A personalised email (Appendix B) was sent to these contacts from Western Europe in June 2015. They were presented with the two-round data collection process and invited to take part in the study. Participants were incentivised to participate by accessing early data between round one and two. Only panel members who had participated in round one were invited to take part in round two (Appendix D).

Participants were from environmental agencies, local councils, recycling companies or were waste and resource management academics (§3.2.1). They were based in Western Europe: the UK, Germany, Portugal, Belgium, Ireland or Romania. Their professional experience was mostly on waste management and environmental issues, not necessarily on small electronic devices. The aim was to gather a panel as wide as possible and not to limit to small electronics. The reasoning was that even though they would not be professionally engaging with small electronics, they would be aware of the challenges posed by small e-waste and could use their professional and personal experiences to relate to mobile and smart phones end-of-use decisions.

It is worth highlighting that the Delphi panel largely comprised waste and resources management professional and academics. It is debatable that their views - influenced by their professional expertise - matches the views and expectations of young adults. In addition, it is valid emphasizing that the views of mobile phone producers and retailers were not sought as it was felt that they may face potential conflicts of interest.

#### 4.1.5 Data collection and data analysis

##### 4.1.5.1 Round 1 data collection

Round one used Survey Monkey to gather data using 5-point Likert scales. Survey Monkey is widely-shared and cloud-based with a user-friendly interface. Likert scales are a commonly used scale to gather data with Delphi (Onwuegbuzie et al., 2010). They are easily understood by panel members as employ commonly used language. In this study, a 5-point Likert scale ranging from “strongly agree” (1) to “strongly disagree” (5) was used to measure each factor presented.

This study obtained ethical approval by the University of Southampton (reference number #12419). 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 any prior consent from the research team. They were given contact details for an ethics officer in case of any concerns and were invited to contact the research team for any queries. Prospective participants were informed that by entering they survey they were registering their informed consent.

Round one’s questions were divided into four categories and presented in the following order: sell, reuse, recycle and discard. They represent common outcomes for mobile and smart phones as end-of-use devices, although repair was not included in this data collection as the focus of the study was to identify factors leading to storage decisions. Participants were required to identify factors that prevented end-of-use devices from being sold by their owner, reused, recycled or factors that would favour discarding. They were presented in a decreasing order implying the most beneficial outcome for the owner the environment. To resell a device suggests a monetary reward as well as the reinsertion of the device into a usage cycle. To reuse an end-of use mobile or smart phone entails the reinsertion of the device into the economy (Binnemans et al., (2013). To recycle prevents environmental harm and some resources might be retrieved but the primary function of the device is lost (Simoni et al., 2015). To discard involves environmental harm and the cancellation of the device primary function (Silveira and Chang, 2010).

Factors investigated were selected from the waste management and behavioural economics literature (Table 2.1), as well as factors related to mobile and smart phone characteristics, such as devices' small size (Table 4.1). Factors were selected from the most commonly used models in waste management describing end-of-use decisions for household recycling, such as the TRA (Fishbein and Ajzen, 1975), TPB (Ajzen, 1991) or MGB (Carrus et al., 2008). Factors selected from behavioural economics theory and related literature were those associated to emotions and the endowment effect (Thaler, 1980; Knetsch, 1989; Kanheman and Tversky, 1991).

Table 4.1: Summary of factors investigated stemming from the waste management and behavioural economics literature for mobile and smart phones end-of-use decisions

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

At the end of each of the four main categories investigated, participants could make comments in a “free text” box. During round one, participants were presented with 69 different factors: 18 for “sell”, 9 for “reuse”, 23 for “recycling” and 19 for “discarding”. Figure 4.1 illustrates a typical statement panel members would be presented with in round 1. The full list of statements available in Appendix C.

| | 1. Strongly agree | 2. Agree | 3. Neutral | 4. Disagree | 5. Strongly disagree |
|---|---|---|---|---|---|
| When deciding to give away the device, users might feel parting from it as an emotional loss. The positive feeling associated to the act of giving does not overcome the sensation of loss. | ○ | ○ | ○ | ○ | ○ |
| The device is more useful as a spare, better not to give it away. | ○ | ○ | ○ | ○ | ○ |

Figure 4.1 Example of factors presented to panel members with a 5-point Likert scale

Once round one’s 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 (§3.2.1). This analysis formed the basis for structuring round two of the Delphi survey (Appendix E). A positive CVR value indicated that at least half the panel members agreed or were in strong agreement with a particular statement made in the survey (Appendix C). Following Lawshe’s (1975) recommendations for panels exceeding 40 members, the cut-off point was set at a CVR value of 0.29. Meaning that factors / responses obtaining less than 0.29 should be disregarded for the next round. Kim et al. (2013), in their Delphi survey for selecting e-waste priorities, also used the same method and cut-off value. Internal-consistency reliability was tested for Likert scales using Cronbach’s Alpha; values higher than 0.7 indicate a reliable scale (Litwin, 1995).

Qualitative data collected after each end-of-use alternatives from a “free text” box were inserted into word cloud software[1]. The system is based on word frequency: the larger the word the most frequently cited.

#### 4.1.5.3 Round 2 data collection and analysis

Once factors were selected by panel members during round one using the CVR cut-off value, factors were fed into a cloud-based software PAPRIKA (Potentially All Pairwise RanKings of all Alternatives) (Hansen and Ombler, 2008). The objective of round two was to measure the prevalence of categories against one another by assessing the factors’ strength through pair-wise comparison. Following Hansen and Ombler’s (2008) PAPRIKA method (based on pair-wise comparison), factors were ranked according to their CVR values (Lawshe, 1975; Hansen and Ombler, 2008). The method developed by Hansen and Ombler (2008) presented respondents with individual pairs of choices. Respondents had three possibilities. They could decide if a pair was strictly superior, strictly inferior or equal (Table 4.2).

Table 4.2 Decision example for the PAPRIKA method. > stands for “superior to”, < for “inferior to” and = for “equal to”

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

PAPRIKA associated with Delphi has not been used in the past but this research has based its data collection method on a similar pair-wise comparison method: the Analytical Hierarchy Process (AHP) (Saaty, 2008, 2013). At the time of the data collection there was no user-friendly and affordable online AHP method and PAPRIKA was freely made available to academics to encourage its diffusion (Hansen and Ombler, 2008). AHP has been used in several domains such as reverse logistics, energy policy or employee recruitment (Bouton et al., 2016; Hsu et al., 2010; Ishizaka et al., 2016; Varmazyar and Nouri, 2014).

[1] https://www.jasondavies.com/wordcloud/

AHP is a decision science method developed by Saaty (2008, 2013). Its design enables decision-makers to break down complex problems requiring decisions into smaller manageable subsets that can be compared with each other. The technique relies on human decision-making by comparing alternatives. Saaty (2008) recommends four fundamental steps in setting up the decision-making process: defining the problem, structuring the decision hierarchy, constructing a set of pairwise comparisons with each alternative available, and using the scores obtained from the pairwise comparisons to determine priorities. Table 4.3 shows examples of the calculations performed once pairwise comparisons are completed by the decision-maker. Pairwise comparison is the process of contrasting pair of alternatives and assigning a score. Scores are then computed in the right-hand column labelled “An”; the higher the score, the more desirable the alternative.

Table 4.3 Matrix illustrating AHP calculation principles. K represents different alternatives compared pairwise. Comparison results measured in conjunctive cells

| **K** | **A1** | **A2** | **…** | **An** |
|---|---|---|---|---|
| **A1** | 1 | a12 | … | a1n |
| **A2** | 1/a12 | 1 | … | a2n |
| **…** | … | … | … | … |
| **An** | 1/a1n | 1/a2n | … | 1 |

One of the main advantages of AHP is the identification of sets of criteria or categories bearing more weight than others, therefore providing additional information to the decision-maker. This outcome is not possible with Likert scales as alternatives can be ranked overall but have not been compared to one another. AHP is an iterative method gradually increasing the value of information obtained. However, one drawback is the difficulty in structuring the decision problem with relevant alternatives. The systematic comparison of alternatives by panel members required is repetitive and can lead to inaccuracies due to panel members’ potential weariness (Ishizaka et al., 2016). Each alternative needs to be dissected with each criterion. For each criterion, the decision-maker assigns a score ranging from 1 to 10, 10 being the highest preference expressed by the decision-maker.

An alternative to AHP is PAPRIKA, 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). This results in fewer decisions for Delphi panel members (Hansen and Ombler, 2008). With AHP, three criteria with four alternatives require 64 decisions in total by each panel members (4 x 4 x 4) and each decision requires panel members to allocate a score ranging from 1 to 10. By comparison, PAPRIKA requires 50% fewer decisions on average (Hansen and Ombler, 2008), as the method only presents undominated pairs requiring a decision. Each pair requires evaluation of the alternatives (stronger, weaker or equal as in Table 4.2), making the decision-making process more straightforward than AHP using Likert scales. But to achieve this efficiency, PAPRIKA needs criteria to be ranked prior to the start of the data collection, to determine which alternatives could be dominated by another. Therefore, round one used Likert scales to rank factors within each category. Round two, using the PAPRIKA method, assessed the weight of each category in the overall end-of-use decision-making process.

The difference with AHP is that criteria need to be ranked prior to data collection. AHP does not require the decision-maker to rank criteria when aggregating them in each category, which results in a higher number of potential answers as the system does not automatically process dominated pairs. With PAPRIKA, all pairs that were not strictly dominated were presented for decision and automatically ranked pairs that were strictly dominated. All pairs that were not strictly dominated were presented for decision. Another advantage of PAPRIKA over AHP is the more natural decision-making process (Hansen and Ombler, 2008) (Table 4.2). Instead of using a 10-point Likert scales, panel members are presented with pairs of alternatives and select which pair dominates, or if they are equal. PAPRIKA has been both used in several studies (Byrne and O'Regan, 2014; Nielsen et al., 2014; Smith et al., 2014; Martin-Collado et al., 2015). Hansen and Ombler (2008) recommend loading maximum 4 factors per category to limit potential respondent's fatigue. However, although PAPRIKA's mathematical accuracy has been recognised by several awards (Hansen and Ombler, 2008), the method is not as widely known as AHP. Hansen and Ombler (2008), have created an open web-based service based on PAPRIKA to academics to conduct any type of data collection (1000Minds[2] and improve the dissemination of the method).

[2] https://www.1000minds.com/

## 4.2 Results

### 4.2.1 Demographics

Of the 205 participants who were invited to take part in round 1 of the Delphi study, 103 panel members accessed the survey and 77 completed it entirely. From these 77 respondents, 44 subsequently completed round two. Response rates were thus 38% and 57% for round one and round two, respectively.

Table 4.4 Delphi round contacts and response rates

| | Contacts | Round 1 | Round 2 |
|---|---|---|---|
| Numbers | 205 | 77 | 44 |
| Response rate | | 38% | 57% |

More than half of all respondents had more than 10 years of experience in the field and more than three quarters of respondents had more than five years of experience (Figure 6.1).

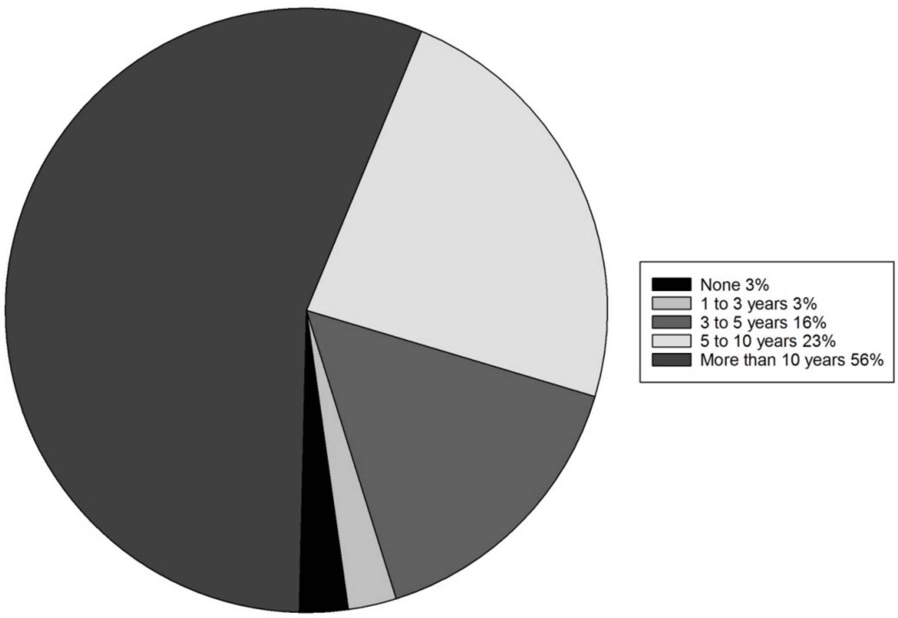



Figure 4.2 Summary of Round 1 Delphi panel participants' experience in waste management (categorised as years of professional experience)

Three quarters of the respondents came from the UK, Germany and Belgium and more than a third of respondents came from the UK. Some 18% of respondents came from Austria, Portugal, Finland and Ireland. The remaining 5% of the panel came from Italy, Brazil, The Netherlands, Romania and the Czech Republic (Figure 4.1). The panel composition fits expectations as a large majority is from Western Europe and a significant number of panel members come from the UK.

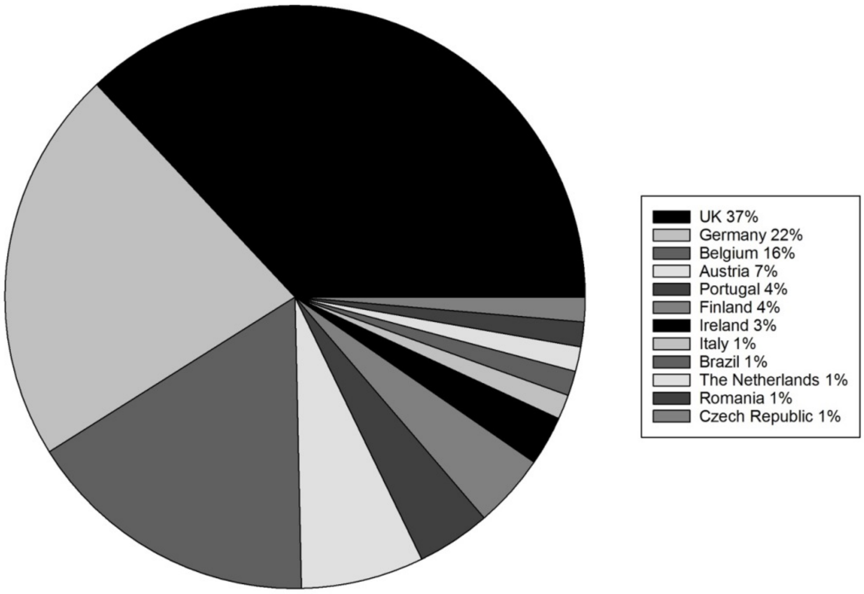



Figure 4.3: Summary of Round 1 Delphi panel participants' country of practice

**4.2.2 Delphi round 1**

Cronbach's alpha for Likert scales measuring sell end-of-use decisions is 0.71, for give-away end-of-use decision 0.6 for recycle end-of-use decisions 0.77, for discard end-of-use decisions 0.84. Although the give-away Cronbach's Alpha is close to the cut-off value set at 0.7, all scales are strongly reliable. Eventually only a single factor from the give-away end-of-use decisions was retained by panel members.

Factors that were deemed as strongly relevant or strongly irrelevant using the Content Validity (CVR) ratio set at 0.29 are displayed in Table 4.5. Table 4.5 represents Delphi round one results illustrated from Table 4.1 and with CVR scores obtained. Only factors with a CVR score >0.29 are retained (Lawshe, 1975) up to a maximum of four factors as per PAPRIKA recommendations (Hansen and Ombler, 2008). Factor ranking is indicated for each category using CVR values in decreasing order.

CVR scores in excess of >0.29 indicate strong agreement from panel members. Factors where panel members were in strong agreement are included in Table 4.5. It was decided to include in the analysis the factors where the panel members were in strong disagreement (CVR score <0.29) (Table 4.6).

Table 4.5: Summary of factors investigated stemming from the waste management and behavioural economics literature for mobile and smart phones end-of-use decisions. CVR scores are shown in parentheses and numbered in decreasing order

| Categories from literature review | Factors | Authors | Mobile and smart phones end-of-use decisions | | | |
|---|---|---|---|---|---|---|
| | | | Sell | Give away | Recycle | Discard |
| Norms and attitudes | Lack of social pressure | Barr et al. (2001) | | | X | X |
| | Lack of ethical values | Chan and Bishop (2013) | | | X | X |
| | Lack of environmental values | Barr et al. (2001) | | | X | X |
| | Lack of altruistic values | Shaw (2008) | | | X | X |
| | Lack of positive attitude towards recycling | Thogersen (1994) | | | X | X |
| Experience and self-efficacy | Limited experience | Barr et al. (2001) | 3 (0.29) | | X | X |
| | Complex process | Harder and Woodward (2007) | X | | X | |
| | Limited awareness | Gutierrez et al. (2010) | X | | 4 (0.46) | |
| Convenience and time | Inconvenient process | Chan and Bishop (2013) | X | | X | X |
| | Time in storage | Gutierrez et al. (2010) | | | 1 (0.72) | 4 (0.55) |
| | Time consuming / saving | Saphores et al. (2009) | 2 (0.31) | | | 1 (0.64) |
| | Immediate decision | Gutierrez et al. (2010) | X | X | | |
| | Delayed decision | Gutierrez et al. (2010) | X | X | X | |
| Device characteristics and status | Small size | Perez-Bellis (2015) | 1 (0.51) | 1 (0.52) | X | X |
| | Unbroken device | Barr et al. (2013) | | | 2 (0.62) | |
| | Quantity in storage | Karim Ghani et al. (2013) | | X | | 2 (0.61) |
| | Device obsolescence | Gottberg et al. (2006) | X | X | | X |
| Emotions and utility | Utility | Thaler et al. (2010) | X | X | 3 (0.62) | 3 (0.56) |
| | Regret felt | Tversky and Kahneman (1992) | | X | | |
| | Emotional loss | Johnson et al. (2012) | | X | | |
| | Lack of positive emotional reward | Carrus et al. (2008) | | | X | |
| | Irreversible decision | Ramani and Richard (1993) | | | X | |

Table 4.6 Delphi round 1 results for factors with CVR scores <0.29. Factors are ranked in decreasing order of importance for each end-of-use category

| Categories | Factors | CVR Score |
|---|---|---|
| **Sell** | Selling this type of device is costly. | -0.88 |
| | Users tend to resell their device immediately after acquiring a new one. | -0.56 |
| | There could be a more convenient opportunity in the future to resell this type of device; better to store it at home. | -0.48 |
| **Give away** | Users tend to give their device away immediately after acquiring a new one. | -0.39 |
| **Recycle** | Recycling this type of device is costly. | -0.87 |
| | Users have a limited experience in recycling household waste, thus tend not to recycle this type of device. | -0.49 |
| | Recycling this type of device is time consuming. | -0.39 |
| | Recycling this type of device is not convenient. | -0.34 |
| | Users lack ethical values, thus they don't recycle this type of device. | -0.34 |
| | There could be a more convenient opportunity in the future to recycle this type of device; better to store it at home in the meantime. | -0.31 |
| | The recycling information gathering process is complex, better not to recycle the device and store it at home. | -0.30 |
| | Users lack altruistic values, thus they don't recycle this type of device. | -0.29 |
| **Discard** | Obsolete devices tend to be more recycled than discarded. | -0.37 |

Participants could add short comments for each of the four main categories if they felt that some additional factors should be considered. The most frequent factor cited by panel members preventing resell, reuse, recycle or favouring discard decisions is concern regarding data security (Figure 4.4).


Figure 4.4 Word cloud created from Delphi qualitative data from respondents for all four investigated categories; the larger the word, the more frequently cited

As advocated by Hansen and Ombler (2008), factors with CVR scores more than 0.29 and using a maximum of four factors per category were retained for round two (Table 4.5 – green highlights). Keeping a maximum number of factors per category limits respondents' fatigue whilst allowing the computation of enough combinations to make the results valid and reliable (Hansen and Ombler, 2008). For each category (sell, give away, recycle and discard), factors were input in decreasing order to respect the strictly dominated principle (Hansen and Ombler, 2008; §4.2.5.3) The aim of round one was to generate a CVR score for individual factors and the aim of round two was to measure the relative importance of factor decision / categories. After applying CVR and establishing a cut-off point of 0.29 (Lawshe, 1975), three factors were retained for selling decisions, one for reuse, four for recycling and four for discarding (Table 4.5). As the single factor for reuse was the same as for resell (size allowing for convenient storage), the decision was made to merge reuse and resell categories for round two of the Delphi study (Table 4.5). The concept of utility (Tversky and Kahneman, 1979) was retained over factors relating to emotions such as regret or emotional loss. From the waste management literature (Table 2.1), concepts such as experience, awareness, convenience (related to device size), time in storage and unbroken status were selected.

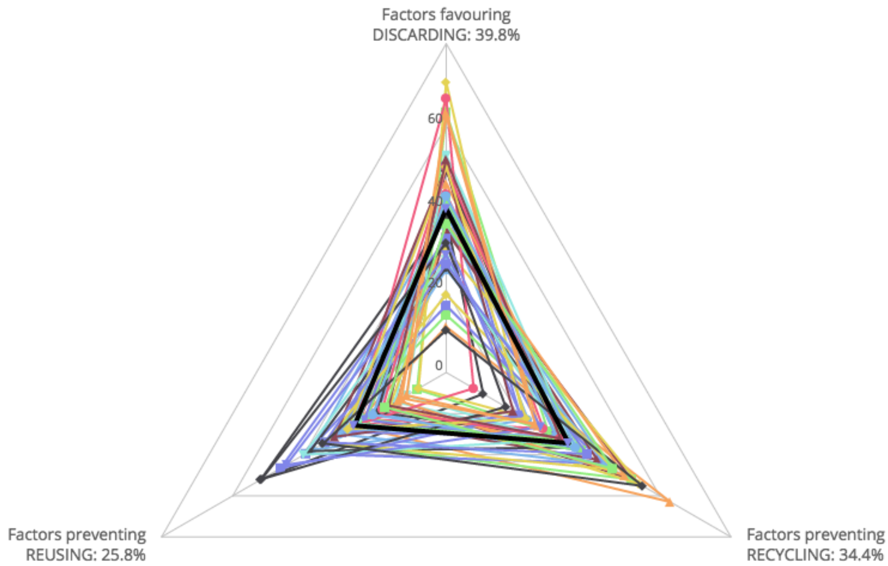



Figure 4.5: Round two results illustration. Each coloured line represents a panel member decision (Table 4.2). The thick black line illustrates the average decisions for all panel members. Numbers represent average weight of decision category when results from all panel members are aggregated

Using the coding column from Table 4.2, the following factors (Figure 4.3) were deemed of importance: time, utility, awareness, size, experience and quantity. Resell and reuse factors were similar and aggregated into a single "reuse" category. There was only one factor from the "giveaway" category retained from round 1 (Table 4.5). Following recommendations from Hansen and Ombler (2008), it was considered logical and appropriate to merge the sell and reuse (give away) categories with the small size factor.

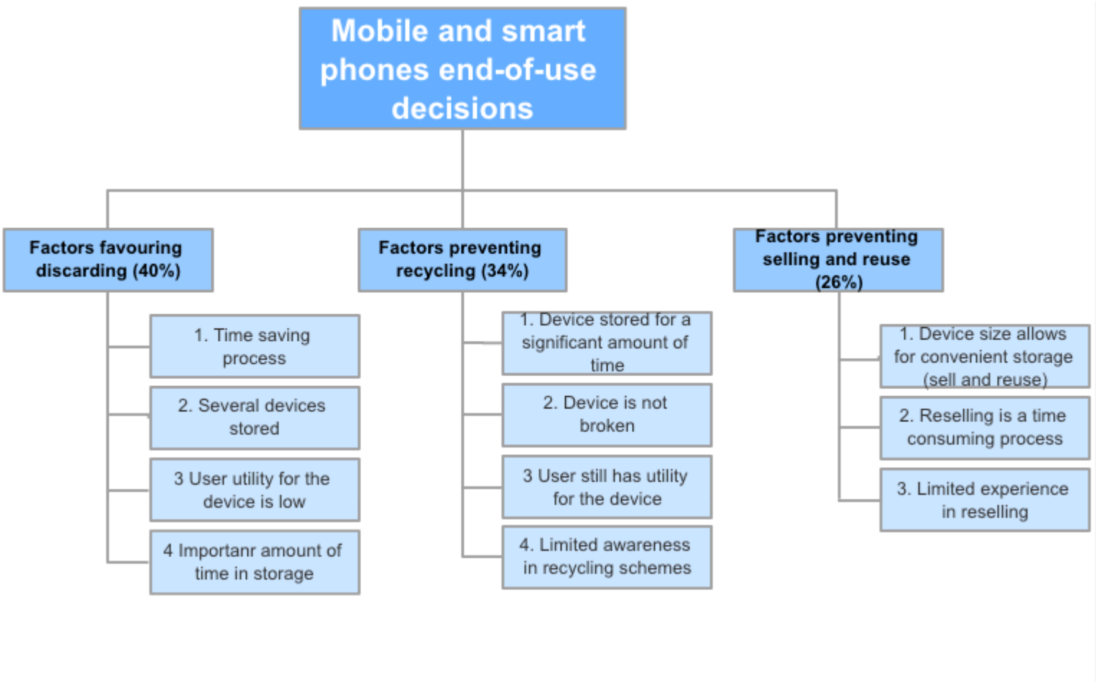



Figure 4.6 Round 2 factors ranking in decreasing order of importance categorised as per end-of-use decisions (Appendix E). Single reuse factor merged with sell factors (§4.3.4). Percentages indicate Delphi round 2 results with end-of-use prevalence (Figure 4.5)

Once all panel members have decided for each pair presented (Figure 4.1), the software presents the criteria with the decisions aggregating panel members' choices (Table 4.2; Table 4.3). Criteria favouring discarding represent 40% of decisions, followed by criteria preventing reuse at 34% and 26% for criteria preventing reuse. Factors favouring discarding decisions were thus cited by panel members more often than factors from preventing recycling and more often than factors preventing selling and reuse (Figure 4.6).

The factors that have been identified through the Delphi study reveal that they pertain to user preferences, device characteristics or sometimes both (Table 4.7). Time-saving or time-consuming, marginal utility expressed, data confidentiality, limited awareness or experience can be associated to user preferences. They express the decisions that have been made to discard, recycle or reuse following their inclination to save time, that they still have a marginal utility for the device being stored away, they have limited information or experience and would rather not engage in an end-of-use activity such as selling or reusing or they are concerned about the data that is still stored on the device and feel it is safer to keep the device unused and stored away. These factors are not part of the "classic" waste management approach where factors such as lack of altruism or lack of environmental concerns tend to explain end-of-use behaviour, more specifically the absence of recycling decisions. On the other hand, the absence of decisions, for example to not recycle, to not reuse or to not sell, can be explained by mobile and smart phones' characteristics, namely their small size. It is apparently more convenient to leave the device in storage due to its small size rather than engaging in time consuming end-of-use activities.

Table 4.7 Delphi study factors summary after rounds 1 and 2 data analysis

| **Discard** | **Recycle** | **Sell / reuse** |
|---|---|---|
| Time saving | Time in storage | Small size |
| Quantity | Not broken | Time consuming |
| Marginal utility | Marginal utility | Limited experience |
| Time in storage | Limited awareness | Data confidentiality |
| Data confidentiality | Data confidentiality | |

## 4.3 Discussion

The discussion follows factors in their order of importance within each end-of-use decision category. Utility factors were considered among three end-of-use categories and time factors amid two categories. Although these factors had to be ranked for round two of the Delphi study to be performed, the aim of the discussion is to establish generic trends that could be exploited in a later quantitative analysis. It was decided, therefore, to first discuss utility and then time factors. All the other factors were present only once per category and discussed following their end-of-use decision category decreasing order of importance. Consequently, the overall structure of the discussion is as follows: utility, time, quantity in storage, unbroken status, lack of awareness, size, lack of convenience and lastly data concerns (as it was mostly cited by panel members but was not integrated in the data analysis as only constituted of qualitative data).

### 4.3.1 End-of-use categories, consequences for the environment and the circular economy

Delphi round 2 has enabled a determination that end-of-use decisions about disposal (i.e. discarding) were more prevalent than end-of-use decisions preventing recycling and end-of-use decisions preventing selling or reusing (Figure 4.6). The consequences of so-called “discarding decisions” may have significant impact(s) on the environment. Smart phones, for example, now tend to have built-in batteries (iFixit, 2016). Bigum et al. (2013) reported in Finland that 20% of discarded batteries were built-into small e-waste. When disposed of in the general refuse and not captured in the recycling stream, battery leachates can contaminate soils and generate fire hazards (Terazono et al. 2015). Mobile and smart phones also contain potentially toxic metals that may be released into the atmosphere when incinerated (Oguchi et al., 2008).

End-of-use decisions preventing recycling (Figure 4.6) represent a barrier and a lost opportunity to retrieve valuable materials such as precious metals and rare metals (Welfens et al., 2016). These metals are virtually non-existent in Western Europe as a geological resource and thus need to be imported (Massari and Ruberti, 2013), unless urban mining works. Increasing the amount of recycled small e-waste would reduce our dependency on such materials (Binnemans et al., 2013).

End-of-use decisions preventing selling or reusing (Figure 4.6) unwanted mobile and smart phones have an impact on the number of stored devices and the lack of secondary-devices not being reinserted into the economy. Increasing the number of reused and sold devices by owners would have a positive effect on the environment as fewer new handsets would need to be manufactured (EPA, 2018); therefore reducing resources depletion and $CO_2$ emissions in the atmosphere (Arora et al. 2017).

The next sections present a discussion of the most prevalent factors across all end-of-use decision categories. Factors are discussed in decreasing order of importance.

#### 4.3.2 End-of-use decision factors

End-of-use factors are discussed in order of prevalence: time, utility, quantity stored away, unbroken status, limited awareness, small size, time consuming and data concerns.

##### 4.3.2.1 Time

###### 4.3.2.1.1 Long time in storage prevents recycling

Time in storage has an influence on decisions to discard (or not) as well as non-recycling decisions. Mobile and smart phones tend to be stockpiled for some time before a decision is taken regarding their fate (Figure 4.6; Table 4.5). Sabbaghi et al. (2015) regard “time-in-storage” for e-waste as being positively related to the time an item has been used; the longer an electronic item has been used, the more time it will spend in storage. These unused devices could have a higher utility if reused or recycled, depending on their functional status. Their components could be source of secondary materials for use in the manufacture of other electronic products; some of their rare or precious metals retrieved for different purposes (Welfens et al., 2016). Not only do stored unwanted mobile and smart phones represent a lost opportunity for recycling of their constituent materials, they represent a threat to the environment.

###### 4.3.2.1.2 Long time in storage favours discarding

A long time in storage tends to favour discarding of mobile and smart phones (Figure 4.6; Table 4.5). This echoes the findings from Gutierrez et al. (2010) who argued that the longer electronic items are stored, the more likely they will be discarded in the general refuse. Similarly, Perez-Belis et al. (2015) estimated that e-waste is usually stored between 2 and 5 years before 50% is discarded. Discarded mobile and smart phones have a negative impact on the environment, if being lost in the general waste stream. Not only their resources are not harnessed to be reused after being recycled, but they can be highly polluting for both soils with acid leachates (Terazono et al. 2015) and for the atmosphere if incinerated (Oguchi et al., 2013).

###### 4.3.2.1.3 Discarding is time saving, especially if stored away for a long time

Delphi round two highlights that time-saving favours discard decisions for mobile and smart phones at their end-of-use (Figure 4.6; Table 4.5). Time-saving in this case is associated with convenience. It is more convenient and time-saving to discard mobile devices in the general refuse than to take them to a recycling point. Devices in working order might be resold, or given away to a friend or family, but devices in non-working order have a high chance of being discarded due to recycling facilities that are inconvenient from a user perspective. Instead of being recycled, small e-waste is stored away. Small e-waste being stored away may become a nuisance after it is being “rediscovered” several years after. Given the (perceived) inconvenience of recycling facilities in the sense that one has to travel to them, it may be considered more convenient and quicker to simply discard it in the general refuse, with the environmental consequences and lost opportunities associated with these decisions.

#### 4.3.2.2 Utility

##### 4.3.2.2.1 Marginal utility for the device prevents recycling decisions

If users still have utility for the mobile or smart phone, they would rather store it away than recycle it (Figure 4.6; Table 4.5). The retained utility they have for their device means they would rather keep it for a later uncertain use, rather than recycling it, potentially “foregoing this utility”. The “cost” associated with storing unwanted small e-waste is minimal given a device’s small size and consequent ease of storage.

##### 4.3.2.2.2 Low user utility for the device favours discarding decisions

However, if the user utility for the device is at the low end, compared to a higher utility for a device that could reused, it might be discarded in the general refuse (Figure 4.6; Table 4.5). Perez-Belis et al. (2015) found that small e-waste with very low utility levels tend to be discarded. The secondary device has been stored away and a primary device is now in use, reducing the probability that the stored device will be used in the near future and increasing the likelihood that it will be left in storage.

##### 4.3.2.2.3 User utility for the device is higher if kept in storage than if resold

There appears to be a utility level that prevents decisions to sell or reuse (Figure 4.6; Table 4.5). Its utility level is sufficient to convince users not sell it or give it away to an acquaintance. The utility felt for the device by the present owner is higher than if being resold or given away. This means that the utility associated with the monetary reward or the utility associated with the emotional reward is lower than the utility if kept in storage for a potential reuse. Keeping redundant devices is common practice (Ongondo and Williams, 2011) but it is notable that, despite the possibilities to recycle, sell or give away, some users still consider their device to have a higher utility if kept in storage unused.

#### 4.3.2.3 Several devices in storage favour discarding decisions

When several mobile devices are stockpiled, there are more likely to be discarded in the general refuse (Figure 4.6; Table 4.5). To store several mobile devices implies they have been unused for an extended period and users have a low utility for them (Figure 4.6; Table 4.5). These recurring themes are supported by Gutierrez et al. (2010) and Perez-Belis et al. (2015). This device accumulation supports the idea that recycling facilities are not convenient and the stored devices have a higher utility for users than if sold or given away.

#### 4.3.2.4 Unbroken devices prevent recycling decisions

Unbroken phones tend not to be recycled (Figure 4.6; Table 4.5). When a device is in working order, it has more utility as a usable handset, compared with a phone destroyed to retrieve its components' secondary market value. Ongondo and Williams (2011) estimated that 59% of students replaced their phones because they were broken and 28% replaced their phone annually. When this study was undertaken in 2011, Nokia was the mobile phone market leader with 27% market shares and smartphones were barely emerging, as Apple had a 3.9% market share (Gartner, 2012). In 2017, Nokia had 1% market share, whilst Apple and Samsung jointly captured 36.2% of the market (IDC, 2018).

Today Apple and Samsung release flagship models every year during much-publicised global events largely anticipated by consumers and technology specialists (Apple, 2016; Samsung, 2017). Users replace their mobile device every 30 months on average (The Guardian, 2017). Users replace their device to keep up with operating system upgrades, technological advances and fashion trends (The Economist, 2016), not because they are broken. The planned obsolescence has inflated the number of devices manufactured every year. This has a direct impact on the number of devices being stored as unbroken and not being sold, reused or recycled. In 2017, close to 2 billion mobile devices and 75% of them being smart phones, were shipped worldwide from factories (IDC, 2018). There are now more mobile devices in service than humans on the planet (International Business Times, 2014).

#### 4.3.2.5 Users have limited awareness of recycling opportunities

Low awareness of recycling opportunities is an obvious barrier to recycling (Figure 4.6; Table 4.5). Welfens et al. (2016) support this view, especially with regards to young consumers. They argue that mobile device collection systems should be located near consumers and present for a significant amount of time to raise awareness over the long term. To alter durably consumer routines, "informal" reminders need to be placed. Consumers seeing regularly collection bins or collection opportunities might engage more in these activities. The case can be made with battery collection points located in stores and more specifically in large (largely UK-based) supermarkets such as Tesco, Asda or Sainsbury's (Asda, 2018; Sainsbury's, 2018; Tesco, 2018). In 2014, close to 200,000 tonnes of batteries were collected and recycled by Asda (Asda, 2018). Silveira and Chang (2010) reported that some US school children are encouraged to engage in races to bring back mobile phones and their schools receive funding accordingly. The earlier awareness can be induced, the more likely this normative behaviour might become natural and collection / recycling decisions would be made regularly by these consumers in the future.

However, frequent reminders might not translate into higher awareness. A takeback programme ran by Motorola in Brazil was almost unknown to mobile phone users (Silveira and Chang, 2010). Similarly, Yla-Mella et al. (2015) found that high awareness levels did not translate into mobile phone recycling behaviour in Finland. Most of the respondents were aware of the importance of recycling mobile devices but 85% of them still stored unused devices within their household and 55% of respondents had at least two devices in storage. Limited awareness could be associated with limited convenience in using these recycling take back schemes. Also, given the trend to stockpile unbroken phones, the association between the unbroken stockpiled device and recycling schemes might be tenuous in consumers' minds.

#### 4.3.2.6 Small device size favours storage and prevents selling or reusing

Mobile and smart phones are conveniently stored due to their size (Figure 4.6; Table 4.5). Saphores et al. (2009) argued that e-waste storage is function of space available. Mobile and smart phones, when stored for a possible later use such as a backup device, do not take up any marked storage space that could be used for other items. Saphores et al. (2009) found that younger people were more likely to stockpile small e-waste than older generations, due to their usually smaller size dwellings. Saphores et al. (2009) argued that e-waste storage is function of space available.

Their small size also presents a threat as small e-waste items tend to be discarded in the general refuse for convenience factors (Darby and Obara, 2005; Gutierrez et al., 2010; Perez-Belis et al. (2015). These devices' small size implies they can easily be forgotten in a "bottom drawer" until the day they are rediscovered. If a decision has been taken not to reuse or not to recycle, it is quite unlikely that, given the time they would have spent in storage, the reuse, recycling or disposal decision will be triggered when they are "rediscovered". When the device(s) reappear from the bottom drawer, for example when a decision to change property is taken, they will either stay, be restocked somewhere else, or they will be discarded as it is the most convenient solution and the device would reappear after having been stored away for a significant` amount of time.

#### 4.3.2.7 Selling is time consuming and is an inconvenient process

Selling devices is considered to be inconvenient and time-consuming (Figure 4.6; Table 4.5). It is unclear from the query formulation and the responses made by panel members if they envisioned online Take-Back Schemes or "bricks and mortar" sites. Therefore, both will be discussed. Ongondo and Williams (2011) estimated that many online mobile phone take-back schemes are convenient to use but usually lack a physical collection point next to high consumer traffic areas such as shopping malls, library or campuses. Given the low figures of reused phones estimated (140 million worldwide; Deloitte, 2017) against the number of new units shipped in 2017 (close to 2 billion; IDC, 2018), the gap illustrates the insufficiency of existing reuse methods.

#### 4.3.2.8 Data concerns

Data and privacy issues prevent users from parting from their mobile device (Figure 4.4). Although this factor was not purposefully included in the Delphi data collection, panel members brought forward this factor across all end-of-use decision categories. Delphi data were collected before the General Data Protection Regulations (GDPR) came into force (European Commission, 2018). The GDPR give more control to individuals on how their data are handled by third party. Professional third parties for trade-in, reuse or recycle have a legal obligation to handle data safely and confidentially. However, Take Back Schemes would rather receive a device that has already been wiped clean of personal data, and regularly give advice on their websites on how to perform these simple yet important steps (Compare and Recycle, 2018; Envirofone, 2018).

Furthermore, there are many software available to erase personal data and third party websites informing users how to erase safely all personal data[3]. Welfens et al. (2016) acknowledge data are difficult to erase fully. Data contained in mobile phones, even more so for smart phones, are very sensitive. Mobile devices are used not only for communication, but also for navigation, information, organisation, financial transactions, bookings, banking and entertainment, such as images and films. These high utilisation levels translate into emotional attachment to devices, making any decision to part from them even more difficult (Welfens et al. 2016). Therefore, it is safer and more convenient to store away an unused phone containing sensitive data, than selling, reusing or recycling it.

[3] https://www.gazelle.com/thehorn/2016/09/20/10-steps-take-recycling-phone/

#### 4.3.2.9 Factors dismissed by panel members

Perhaps as importantly as the factors that have been retained by Delphi panel members, some attention should be given to factors that have been strongly dismissed (Table 4.6).
Among the factors regularly cited by previous studies on recycling decisions, such as the importance of altruistic or ethical values (Table 4.1), Delphi panel members have dismissed them altogether for mobile and smart phones (Table 4.6). They strongly disagreed that altruistic and ethical values would have an influence on mobile devices end-of-use decisions. However, Bortoleto et al. (2012) and Davies et al. (2002) argue for the inclusion of environmental factors in their end-of-use behaviour model. Concerns for the environment are related to waste prevention behaviour. It may be speculated that considering an unwanted mobile or smart phone, especially if still working, one might not perceive the device they were using regularly until recently as "waste". They might not even consider discarding them in the general refuse. They might simply store it away somewhere in their home. Consequently, environmental concerns do not enter the decision-making process when replacing a mobile device at the end of its use.

Evidence from Bigum et al. (2013) showed that 3,129 Danish households discarded close to 90 kgs of WEEE for all categories every year. This amount was composed of batteries and cables wrongfully discarded. Despite knowing the potentially polluting effects of e-waste (Terazono et al. 2015), in the view of Delphi participants, consumers still choose the most convenient option when parting from their electronic waste (Table 4.6). Stockpiled products, especially in working condition, might not be perceived as waste as they might still have an intended utility in the near future. However, when these devices' utility comes close to zero in consumers' mind, they might become considered to be waste. This change of perspective could explain why small electronic products are destined for general refuse.

Panel members also dismissed the relative influence of social norms. Barr and Gilg (2005) stated that successful models to conceptualise and analyse attitudes and actions to address environmental issues should factor in social and psychological elements. Pakpour et al. (2014) demonstrated that TPB-based models explaining higher variance levels (47%) included social and moral norms. The differences between the academic literature and the results from this study could be explained by the nature of small e-waste. When discarding small e-waste in the general refuse, such as mobile phones, it will be unnoticed by peers or neighbours (Shaw, 2008). Therefore, the social and moral activators usually acknowledged in TPB-based studies might have a lesser effect. Panel members dismissed the fact that the more a device was obsolete the more likely it would be recycled. Whilst this statement seems to contradict the perception that time has an influence on device fate, it could also be perceived as the confirmation that obsolete devices tend to be discarded as supported by Gutierrez et al., (2010).

#### 4.3.3 Factors aggregation

The factors discussed can be aggregated into two meta categories: user-based (time saving, utility for the device, time in storage, limited awareness / experience), or device-based (quantity stockpiled, unbroken device, size) (Table 4.7). They are quite different from the waste management literature (Table 4.1) and are rather more “practical”. They are based on user behaviour and the device unique characteristics.

## 4.4 Chapter conclusion

This exploratory qualitative data analysis has identified factors influencing end-of-use decisions for mobile and smart phones associated to user preferences and device characteristics.

Owners’ utility for the device is to be considered, as well as the time the device has been held in storage. Similarly, these factors are influenced by the device’s very characteristics, such as its size, its working order and capacity to store data. It is valid to note these factors have some common aspects. The utility owners have for their device is related to the device characteristics. It could be assumed that utility for the devices will be higher if they have enhanced technical capabilities. The concept of “utility” is central to Behavioural Economics and should warrant further investigation. A limitation should be underlined: convenience sampling has been used to select panel members. Although the response rate and the quantity of respondents has been large.

When considering mobile and smart phones end-of-use factors, “classic” waste and resource management factors don’t necessarily apply. Social pressure, ethical or altruistic values (Barr et al., 2001; Chan and Bishop, 2013) are not relevant to these small electronics. At the end of their use, owners don’t perceive them as “waste” and would rather keep them in storage than engaging in an end-of-use activity that might not fully satisfy their utility. This non-decision to engage in end-of-use activities generates Distinct Urban Mines that need to be exploited.

Future research could confirm the relevance of these factors, especially utility and device characteristics, with a quantitative data analysis and measure their influence on actual end-of-use behaviour.

# Chapter 5: Developing a Model Dedicated to Small Electronics Using the TPB and the Endowment Effect

The quantitative phase of this mixed methods research design is to propose a theoretical model specific to end-of-use decision-making regarding small electronic devices; by confirming prominent factors specific to mobile and smart phones; by measuring the influence of these factors on the storage of small electronic devices; by defining end-of-use profiles based on behavioural factors.

To confirm the findings from the qualitative phase (Chapter 4) stemming from the mixed methods research design (Chapter 3), a quantitative social survey was undertaken among a sample of UK Higher Education Institutions (HEI).

## 5.1 Methods

### 5.1.1 Experimental design: social survey

The data collection of this study is the quantitative phase of the exploratory mixed methods research design presented in Chapter 3. Mixed methods are commonly used to develop different understandings to a phenomenon in social science (Mertens and Hesse-Biber, 2012). The quantitative phase aims at confirming the factors identified in an earlier qualitative phase (Johnson and Onwuegbuzie, 2004, Chapter 4). If the sample is representative, this gives the opportunity to generalise the results to a wider population segment (Hesse-Biber and Johnson, 2015).

### 5.1.2 Pilot survey and survey outline

A pilot survey with ten participants was carried out with PhD researchers, academic colleagues and colleagues working in market data analysis. Some clarifications were made on the concept of utility and rather the term “usefulness” was used for participants, as well the sequencing of some questions to improve the survey flow. The final questionnaire was administered entirely online. The survey consisted of 49 questions, taking approximately 15 minutes to complete, segmented into four distinct categories. In the first category participants were asked to describe their current and primary mobile device characteristics as well as their usage. Semi-open questions were used to identify device make, brand, acquisition date, market value estimates. Dropdown lists were used to ascertain acquisition state or contract type and Likert scales used to measure usage duration over a typical day or their utility for the device. To estimate the devices' market value, participants were asked to use an online aggregator of offers from take-back schemes[4] (TBS) to offer the best possible monetary incentive from the second-hand market. This site was selected as it came in first place on Google searches with the terms "recycling + mobile + phone" in November 2015. Express written approval was sought from the respective website owners and ethically approved by the University of Southampton (Ethics #18705) and Coventry University (P39761). Participants were asked to enter their devices' brand, make and acquisition date to retrieve the device maximal market value. Participants subsequently reported back the data into the survey.

In the second category, participants described if they had unused devices stored away. Semi-open questions and dropdown lists were used to identify the number of devices stored and the reasons they had been stored. In the third section, respondents described if they had ever reused (given to friend or family), sold, recycled or discarded previously-owned mobile devices. Semi-open questions, dropdown lists and Likert scales were used to ascertain device characteristics, contract type, users' utility for their device and stockpiling duration before end of use decision was made. Finally, respondents were asked to provide demographic data and input their e-mail address, if they wanted to take part in the prize draw.

### 5.1.3 Survey of UK university students

The survey was disseminated online to students from two institutions: the University of Southampton (UoS) and the Coventry Business School (CBS), which is part of Coventry University. These two institutions were selected as they have different characteristics. The University of Southampton is from the Russell Group, an association of universities in the UK dedicated to maintaining high research standards. The UoS is a coastal university and has a strong science and engineering research focus. Coventry University is a "Post-92" Institution, a denomination of UK universities who are generally more teaching oriented. CBS is located in the Midlands and has a strong focus on business-related subjects. Only students were invited to participate in this study on mobile and smart phone end-of-use decisions. Student participants were asked to describe the usage of their mobile device, some of the device technical characteristics and to estimate its market value. In addition, they were asked to determine their past end-of-use behaviour for a previously-owned mobile device. For example, if they had already given an unwanted device to a

[4] www.compareandrecycle.com

friend or family, had already sold it, had recycled it or maybe discarded it in the general refuse. Finally, respondents were required to provide some demographic information.

Students are avid consumers of mobile technology. Ongondo and Williams (2011) estimated that 99% of students are equipped with a mobile device and they represent future consumers. University campuses constitute geographical delimited areas. It is convenient to disseminate information via university information systems. Data were collected by a web-based social survey. Survey Monkey was used for UoS. The research team chose Survey Monkey as this platform offers a wide range of possibilities online with the payment version. Ethics approval from Coventry University required the use of Bristol Online Survey (BOS). Both surveys, in terms of the assessment questions were identical, despite the different online methods used, as required by each university.

The survey was disseminated directly to University of Southampton students via SUSSED (a student portal), Facebook groups: Postgraduate, University of Southampton, Current Freshers, International Students and relayed by colleagues over email, between the 7$^{th}$ and the 21$^{st}$ of March 2016 and to Coventry University students via Business course web pages and Facebook groups: Coventry University International Students, MSc International Business, Centre for Global Engagement, during the same period. Ongondo and Williams (2011) used universities information portals to disseminate and students are avid consumers of social media, especially on mobile devices (Kim et al., 2016). Therefore, disseminating the survey on university campus portals and affiliated social media was a reasonable method to connect with as many students as possible in a defined period of time.

### 5.1.4 Social survey structure and data collected

Table 4.7 presents the 13 factors retained by panel members during the Delphi data analysis. It is used to illustrate how the qualitative phase findings were used to inform the subsequent quantitative phase. Table 5.2 lists the entire list of factors investigated during the quantitative data collection. There are three main question categories, the associated dependent variables, data type and scales used. The social online survey gathered data on the mobile device characteristics and associated usage; then questions related to currently stored devices and finally, questions related to demographics.

Table 4.7 from §4.3.2: Delphi study factors summary

| **Discard** | **Recycle** | **Resell / reuse** |
|---|---|---|
| Time saving | Time in storage | Small size |
| Quantity | Not broken | Time consuming |
| Marginal utility | Marginal utility | Limited experience |
| Time in storage | Limited awareness | Data confidentiality |
| Data confidentiality | Data confidentiality | |

Table 5.2 Variable categories, dependent variables, data type and scales used in the online survey

| Categories | Dependent variables | Data type | Scale |
|---|---|---|---|
| Phone characteristics and usage | How long ago was the device acquired | Continuous | Months |
| | Operating system | Categorical | iOS, Android, other |
| | Device acquisition state | Categorical | New, second-hand, refurbished |
| | Contract type | Categorical | Pay as you go, monthly |
| | Average monthly spent | Ordinal | 1 to 5 |
| | Estimated phone current value | Continuous | £ |
| | Estimated phone future value when replaced | Continuous | £ |
| | Phone market value | Continuous | £ |
| | Difference between estimated current value and phone market value | Continuous | £ |
| | Emotion felt when discovering value difference | Categorical | Negative, neutral positive |
| | Replacement time frame | Ordinal | 1 to 5 |
| | Utility | Ordinal | 1 to 10 |
| | Amount of data stored | Ordinal | 1 to 5 |
| | Total daily screen time | Ordinal | 3 to 15 |
| Stored device decisions | Quantity of devices stored | Ordinal | 1 to 5 |
| | Stored due to convenient small size | Ordinal | 1 to 5 |
| | Stored due to utility left | Ordinal | 1 to 5 |
| | Stored due to reselling is time consuming | Ordinal | 1 to 5 |
| | Stored due to limited experience in reselling or recycling | Ordinal | 1 to 5 |
| | Stored due to potential data confidentiality issues | Ordinal | 1 to 5 |
| | Utility when given | Ordinal | 1 to 10 |
| | Utility when sold away | Ordinal | 1 to 10 |
| | Utility when recycled | Ordinal | 1 to 10 |
| | Utility when discarded | Ordinal | 1 to 10 |
| | Time in storage before given | Ordinal | 1 to 5 |
| | Time in storage before sold away | Ordinal | 1 to 5 |
| | Time in storage before recycled | Ordinal | 1 to 5 |
| | Time in storage before discarded | Ordinal | 1 to 5 |
| Demographics | Gender | Categorical | Male, female |
| | Fee status | Categorical | Home/EU, overseas |
| | Degree type | Categorical | UG, PG |

Survey respondents were asked to estimate their smartphone daily screen time. To facilitate the process, respondents had to estimate morning, afternoon and evening screen times. They used a 5-point Likert scale to estimate each period of the day: 1 for less than 30 minutes, 2 between 30 minutes and 1 hour, 2 between 1 and 2 hours, 4 between 2 and 3 hours, 5 for more than 3 hours. Morning, afternoon and evening results were then aggregated into a 13-point scale, ranging from 3 (less than 90 minutes) to 15 (more than 9 hours) per day. This scale was then classified into low (3 to 6 – 90 minutes to 3 hours), medium (7 to 11 – 3 to 5 hours daily) and high (12 to 15 - 5 to more than 9 hours daily) bands.

Likert scales were used to measure utility, amount of data stored, or users' utility for the device. There has been a long and debate whether ordinal data should be treated as interval (Knapp, 1990) with "liberals" using mean and standard deviation to express Likert scale outcomes and "conservatives" refusing to do so. The debate has been ongoing for more than 70 years since Stevens's (1946) seminal paper. "In the strictest propriety, the ordinary statistics involving using means and standard deviations ought not to be used with these scales" (Stevens, 1946:679). Stevens (1946) also recognised that in social science Likert scales are one of the most useful measurement methods to effectively measure human behaviour and "for this 'illegal' statisticizing (sic) there can invoked a kind of pragmatic sanction: in numerous instances, it leads to fruitful results" (Stevens, 1946:679). The ongoing debate has brought some practical solutions when treating ordinal data as continuous. Knapp (1990) advocates to use the same scales among several ordinal variables and Carifio and Perla (2007) recommend using Likert scales with at least 5 points. In this study, Likert scales were treated as ordinal variables and means only used to test hypothesis as described (§ 5.2.5). Internal-consistency reliability was tested for Likert scales using Cronbach's Alpha. High values superior to 0.7 indicate a reliable scale (Litwin, 1995).

#### 5.1.5 Statistical analysis for usage behaviour

Non-parametric tests were used to determine correlation between variables with SPSS. Mann Whitney U (MWU) were applied to grouping variables with 2 levels, such as gender and Kruskall-Wallis (KW) tests to grouping variables with more than two levels. Most of the data collected were categorical and ordinal. Non-parametric tests are preferred in this situation (Mayers, 2013).

MWU tests performed on categorical variables with 2 levels to test the following hypothesis:

**Gender (Male / female)**

H0: Gender has no significant influence over other variables

H1: Gender has a significant influence over other variables

**Degree type (UG / PG)**

H0: Degree type has no significant influence over other variables

H1: Degree type has a significant influence over other variables

**Origin (Home-EU / overseas)**

H0: Origin has no significant influence over other variables

H1: Origin has a significant influence over other variables

KW tests performed on categorical variables with 3 levels to test the following hypothesis:

**Screen time**

H0: screen time has no significant influence over other variables

H1: screen time has a significant influence over other variables

**Reported utility for the device**

H0: Utility has no significant influence over other variables

H1: Utility time has a significant influence over other variables

**Emotions felt**

H0: Emotions have no significant influence over other variables

H1: Emotions have a significant influence over other variables

**Age**

H0: Age has no significant influence over other variables

H1: Age has a significant influence over other variables

### 5.1.6 Emotions reporting and word cloud analysis

Students were asked to estimate their device market value and then retrieve the market secondary value from a website producing market data based on the highest device valuation. Once the respondents were shown the difference between the two valuations, they were required to state their emotion felt by using a single word, for example “disappointment” or “surprise”. When qualitative data contained several words, typographical errors or a sentence, data was formatted to fit in a single word. Words such as “OK” were transcribed into “fine”. Statements that were not understandable or blank were left out from the analysis.

### 5.1.7 Profiles

Profiles were determined based on recent past decisions concerning end-of-use mobile phones. Four categories were defined accordingly: reusers, resellers, recyclers and discarders. Results were then segmented according to these profiles:

Difference between market value and perceived value

Time the device has been in storage before end-of-use decision

Utility for the device prior to making end-of-use decision

Average number of stored devices

Destockpiling incentives

The survey evaluated respondents' usage of their current device, as well as the device estimate and market values. It also estimated the number of devices currently stored and respondents' past behaviour regarding similar devices. The aim was to identify behavioural factors correlated to stockpiling and build profiles based on experience.

5.1.8 Generalisation of observations to the UK student population

To test for sample representativeness, Chi-Squared tests were conducted on three categorical variables: gender (male / female), origin (Home_EU/overseas) and degree type (undergraduate (UG) / postgraduate (PG)). To estimate quantities of stored phones among all UK students, 2015/16 data from the Higher Education Statistics Agency (HESA) were used for an estimated total UK student population of 2,280,825 as the basis for extrapolation.

## 5.2 Results

Results are presented in four main categories:

1. The respondents' phone characteristics and usage
2. The statistical tests performed to identify which variables have the highest correlation with screen time
3. The generation of profiles based on past end-of use decisions
4. The association of profiles and screen time to segment incentives that could trigger a destockpiling decision

Quantitative data obtained from the social survey were computed to extrapolate results at UK university level, to test factors having an influence on stockpiling decisions and to build profiles based on past behaviour. Incentives to "destore" were then segmented according to profiles.

### 5.2.1 Results: overview

This section presents the statistical tests that were performed for sample representativeness, as well as the descriptive data used to illustrate the respondents' phone characteristics. Then, based on based on respondents' number of stored phones, an estimate is generated at UK level.

The survey was made available, in principle, to approximately 22,000 students at UoS and 5,000 students at CBS, i.e. for a total theoretical population of 27,000 students. A total of 515 usable questionnaires was collected at a response rate of 2%; 360 responses were obtained from UoS and 155 from CU.

To test for sample representativeness for all respondents combining both universities, Chi-squared tests were applied to three categorical variables: degree type (undergraduate or postgraduate), gender and origin (home/EU or overseas) (p=0.05 and $X^2$ >=3.84) (Table 5.3). Chi-squared computation with SPSS yielded the following results: gender (p=0.032; $X^2$ =4.574) and origin (p=0.003; $X^2$ =8.842). Both tests should be rejected as $X^2$ values are above the threshold set. It cannot be concluded that the sample is representative of the wider UK student population for gender and fee status.

Table 5.3 Sample representativeness testing. Results indicate that results cannot be generalised as Chi-square values are above 3.84 threshold set by p=0.05 and 1 degree of freedom

| | **All** | **UK Higher Education** | | **Chi-squared (df = 1)** | |
|---|---|---|---|---|---|
| **Categorical variables** | Sample | UK[5] | p-value (0.05) | 3.84 | Results |
| **1.Male** | 54% (275) | 43% (991,670) | 0.032 | 4.574 | Reject |
| **1.Female** | 46% (234) | 57% (1,288,680) | 0.032 | 4.574 | Reject |
| **2.Home / EU** | 77% (401) | 87% (1,969,755) | 0.003 | 8.842 | Reject |
| **2.Overseas** | 23% (118) | 13% (304,895) | 0.003 | 8.842 | Reject |

Likert scales internal-consistency validity

Cronbach's alpha for Likert scales measuring utility for the device is 0.87 and for screen time is 0.7; both scales are reliable as their values are equal or superior to 0.7 indicating high internal reliability (Litwin, 1995; §5.2.4).

[5] HESA 2015/16 https://www.hesa.ac.uk/data-and-analysis/students

### 5.2.2 Mobile devices characteristics

Most students own a smartphone with an Android operating system (OS) from Google (Table 5.4). The next most common OS was iOS from Apple. Students did not use Windows or Blackberry-based OS. There were no feature phones among student ownership; 100% of respondents reported using a smartphone. Eighty-six percent of students acquired their smartphone in a new condition, 12% of acquisitions were second hand and 2% of devices were refurbished. Only a handful of respondents did not provide any information (other - less than 1%). Seven percent of respondents acquired their smartphone in the year of the survey[6] (i.e. in 2016). Fifty-nine percent of respondents purchased their device in 2015. This is the single most important year of acquisition; as 2014 represents 22% of device purchasing, 2013 accounts for 10% and 2012 for 3%.

Table 5.4 Respondents' phone and spending characteristics

| Operating system | Acquisition status | Smart phone acquisition time | Contract types | Average monthly spent | Average data stored | Number stored |
|---|---|---|---|---|---|---|
| Android (62%) | New (86%) | < 3 months (7%) | PAYG (35%) | Less than £10 (33%) | < 8 GB[7] (23%) | 0 (37%) |
| iOS (38%) | 2nd hand (12%) | Last year (59%) | 12 months (11%) | £11 to £20 (30%) | 8 to 16 GB (41%) | 1 (21%) |
| | Refurbished (2%) | 2 years ago (22%) | 18 months (2%) | £21 to £30 (13%) | 16 to 32 GB (19%) | 2 (17%) |
| | | 3 years ago (10%) | 24 months (34%) | £31 to £40 (10%) | 32 to 64 GB (12%) | 3 (10%) |
| | | 4 years ago (3%) | Other (18%) | > £41 (4%) | > 64 GB (4%) | >4 (15%) |

Pay as you go (PAYG) was the most frequent format to access mobile networks (35% of responses; Table 5.4), closely followed by 24-month contracts (34%). Some 16% of respondents selected "other" and commented on their choices. They explained they were using "goody bags" from Giff Gaff, a no-frills mobile network operator, offering data-only plans without air time or text messages. Other comments indicated respondents were using prepaid cards. Almost two-thirds of

[6] Survey conducted in March 2016
[7] GB:

students spent less than £20 per month to service their mobile data access. For the remaining respondents, 13% consumed between £21 and £30, 10% between £31 and £40 and 4% more than £41 per month. Ten percent of respondents declined to answer or selected "not applicable". Close to two-thirds of students (64%) stored between 1 and 16 Gb of data on their device, 19% between 16 and 32 Gb, 12% between 32 and 64 Gb and 4% more than 64 Gb. 2% of respondents selected other or didn't respond to this question (Table 5.4).

### 5.2.3 Mobile devices: stockpiling levels among UK students

Thirty-seven percent of respondents did not have a backup phone, 21% had 1 spare, 17% had 2 backups, 10% had 3 spares and 15% had at least 4 stored devices (Table 5.4 and Figure 5.1).

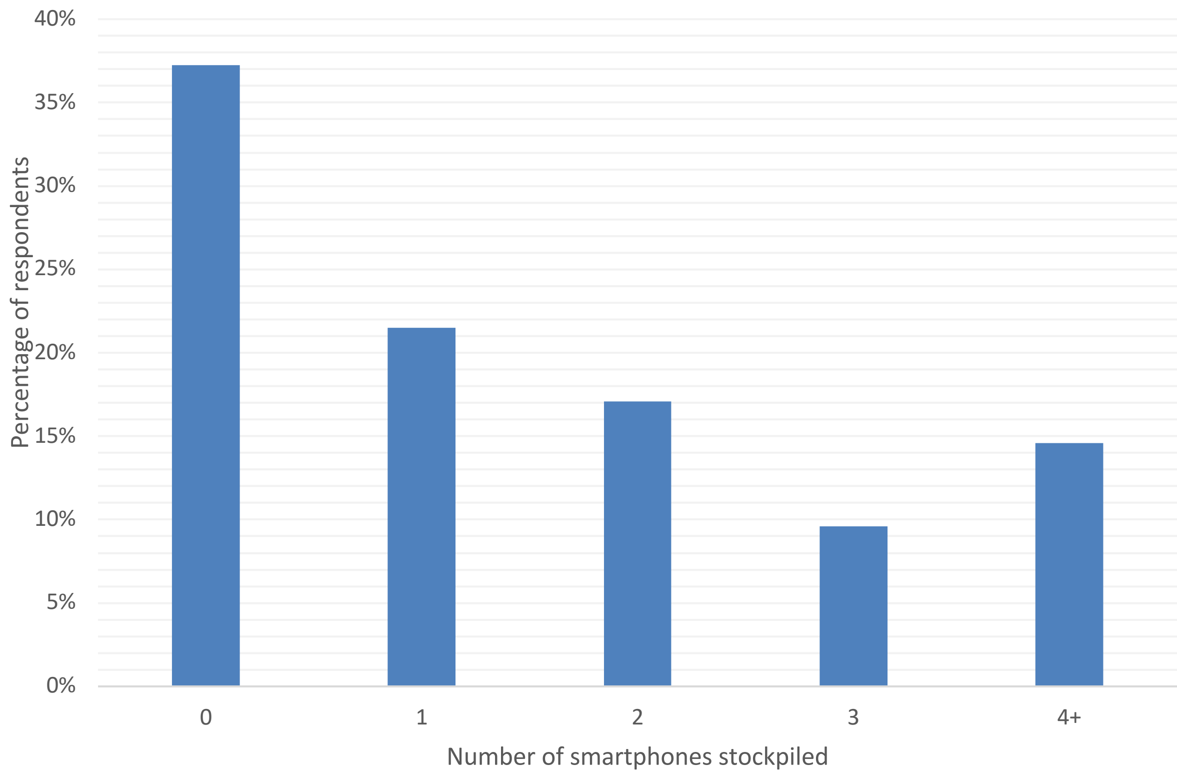



Figure 5.1 Estimated average number of stored mobile devices per respondent

Respondents reported the number of devices stored (Fig. 5.1). They indicated they needed to have a spare device in case the primary one would fail. The study shows that approximately 2.4 million devices are held by UK students as safety stock. Close to 1 million devices are categorised as accessible stock (Table 5.5). However, these estimates should be viewed with caution as the sample is not fully representative of the wider UK student population. It tends to be slightly biased towards male and overseas students. This accessible stock is composed by students who have more than 2 devices stored. Safety stock is composed of 1 device stored being kept if the primary device fails or to be used to avoid damaging the primary device.

Table 5.5 Stored devices extrapolated to UK universities level. Storage of one device is labelled as "safety stock". Stores for two and more devices are categorised as "exploitable stock". Bold values highlight safety and exploitable stocks at UK level.

| | | Number of stored mobile phones | | | | | |
|---|---|---|---|---|---|---|---|
| | (count) | 0 | 1 | 2 | 3 | 4+ | Total |
| Respondents | Male | 99 | 71 | 41 | 21[8] | 41 | 380 |
| | Female | 84 | 43 | 46 | 29 | 34 | 358 |
| | Total | 183 | 114 | 87 | 50 | 75 | 738 |
| Units | Sample | 0 | 114 | 174 | 150 | 300 | 738 |
| | Safety stock | 0 | 114 | 87 | 100 | 225 | 526 |
| | Exploitable stock | 0 | 0 | 87 | 50 | 75 | 212 |
| Units (4480[9]) | Population | 0 | 510,713 | 779,509 | 671,991 | 1,343,981 | 3,306,194 |
| | Safety stock | 0 | 510,713 | 389,755 | 447,994 | 1,007,986 | **2,356,447** |
| | Exploitable stock | 0 | - | 389,755 | 223,997 | 335,995 | **949,747** |

Among the 63% of respondents who indicated they had at least one spare device at home (Figure 5.1), some commented on the reasons why they had a spare. Table 5.5 indicates that 738 phones were in use and storage among the 515 respondents, resulting in 1.43 phones per respondent. A word frequency online software tool[10] was used to estimate stockpiling reasons, sometimes called "word cloud" (Figure 5.2). Qualitative data generated by respondents were coded into a single word. For example, "I have a spare phone at home just in case the main device fails" was coded as "backup".

The five most common words illustrate the most common reasons for storing devices. In decreasing order, these reasons are: backup if primary device failed, device might have a future

[8] For example 21 male respondents indicated they had 3 phone in storage, equalling 63 phone in total.
[9] Weighted average coefficient between sample and UK student population for male and female students obtained from table 5.5
[10] https://wordcounter.net/

utility, future intention to resell or recycle, use as substitute for specific events and don't know what to do with the unwanted device (Figure 5.2; Table 5.5a).


Figure 5.2 Word cloud composed of qualitative feedback given by respondents when asked why they had stored their devices

Table 5.5a The five most common reasons for storing away ranked in decreasing order

| Storing away reasons | % of respondents |
|---|---|
| Backup if primary device failed | 44% |
| Device might have a future utility such as giving to family | 10% |
| Future intention to resell or recycle | 10% |
| Use as a substitute during specific events (music festival) | 6% |
| Keep it as don’t know what to do with it | 5% |

In 47% of the cases the “backup” intention had not been realised (Table 5.5b); meaning that the purpose for which the phone had been set aside had not materialised at the time of the survey. Close to 50% of respondents have stored away their phone but haven’t used it for the intended purpose.

Table 5.5b Backup intention realised at the time of the survey

| Backup intention at the time of the survey | % of respondents |
|---|---|
| Yes | 51% |
| No | 47% |
| N/A | 2% |

### 5.2.4 Behavioural factors associated to smart phone usage among UK students

One hundred percent of respondents owned a smart phone (§5.3.3).

5.2.4.1 Hypothesis testing

Seven hypotheses were tested to determine if independent variables had influence over selected dependent variables (Table 5.2), §5.2.5): gender, degree type, origin, screen time, emotions, utility and age.

Table 5.5c Independent variables with 2 levels tested with MWU. Dependent variables selected with a cut-off value $p < 0.005$ two-tailed (§5.2.5; Appendix K)

| Independent variables (2 levels) | Number of dependent variables |
|---|---:|
| Gender | 2 |
| Origin | 7 |
| Degree type | 2 |

Table 5.5d Independent variables with 3 levels tested with KW. Dependent variables selected with a cut-off X2 value 5.99, df = 2, $p < 0.005$ (§5.2.5; Appendix K)

| Independent variables (3 levels) | Number of dependent variables |
|---|---:|
| Screen time | 15 |
| Emotions | 4 |
| Utility | 6 |
| Age | 5 |

Out of all variables tested (§5.2.5; Appendix K), screen time yielded the highest number of correlated dependent variables (Table 5.5c; Table 5.5d). Out of 25 variables tested, 15 were determined as statistically significant (Table 5.6). Each level of the independent variable screen time (low, medium and high; §5.2.4) has been illustrated for each of the 15 dependent variables using mean values (Appendix L).

They have been ranked in decreasing order according to the test result $X^2$ (Table 5.6). Bold values indicate which level of the independent variable screen time has the most influence on each dependent variable.

Table 5.6 Variables correlated to “screen time” using Kruskall-Wallis testing. Values in bold indicate the highest value for each dependent variable. Standard deviation is showed only for variables of interest in bold and for continuous data (Appendix L).

| **SCREEN TIME** | **Dependent variables** | **$X^2$** | **df** | **P** | **Low** | **Medium** | **High** |
|---|---|---|---|---|---|---|---|
| **$X^2 > 5.99$, df = 2, p < 0.05** | Phone future estimated value | 43 | 2 | 0 | 112 | 149 | **188 (+/- 140)** |
| | Phone current estimated value | 36.16 | 2 | 0 | 173 | 262 | **306 (+/- 190)** |
| | Phone market value | 32.05 | 2 | 0 | 109 | 152 | **188 (+/- 116)** |
| | Monthly spent | 31.1 | 2 | 0 | 1.82 | 2.21 | **2.98** |
| | Data stored | 19.98 | 2 | 0 | 2.07 | 2.42 | **2.75** |
| | Potential data confidentiality issues | 19.94 | 2 | 0 | 1.82 | **2.32** | **2.32** |
| | Devices quantity stored | 18.89 | 2 | 0 | 1.08 | 1.66 | **1.76** |
| | Estimated and market value difference | 13.94 | 2 | 0 | 69 | 117 | **122** |
| | Sold away - how long before decision | 11.7 | 2 | 0.004 | 2.07 | 1.73 | **2.91** |
| | Reselling time consuming | 11.61 | 2 | 0.003 | 1.97 | **2.42** | 2.18 |
| | Convenient storage | 10.58 | 2 | 0.005 | 1.87 | **2.27** | 2.24 |
| | Limited experience in recycling or reselling | 7.68 | 2 | 0.021 | 1.94 | **2.28** | 2.16 |
| | Utility | 7.5 | 2 | 0.023 | 8.03 | 8.24 | **8.31** |
| | Emotion felt coded | 6.54 | 2 | 0.038 | **1.75** | 1.59 | 1.62 |
| | Utility left | 6.42 | 2 | 0.04 | 2.82 | **3.25** | 3.1 |

High screen times are correlated with high phone estimated values (current and future), with high phone market value and with high differences between market value and current estimated value (Table 5.6). Respondents with high screen time had the highest future and current estimates (average of £188 and £306 respectively), as well as the highest phone market value (£188). They reported they spent the most to access the Internet and pay for calls (2.98/5), they had the most data stored on their device (2.75), they felt that data confidentiality could be an issue when making an end-of-use decision (2.32/5), they had more devices stored (1.76), it took them longer to take a reselling decision than others (2.91/5) and they had the highest utility for their device in current use (8.31/10). Although, it is debatable to use averages for Likert scales, they are simply used to illustrate differences between low, medium and high screen time levels, within a non-parametric test. The results are statistically significant as per the KW tests displayed in Table 5.6.

Respondents with medium reported screen time felt that data confidentiality could be an issue when making an end-of-use decision (2.32/5) – similarly to respondents with high screen time, felt more strongly that reselling was time consuming (2.42/5), that the device size allowed for convenient storage (2.27/5), that limited experience in reselling or recycling was a factor favouring stockpiling (2.28/5) and that marginal utility for stored away devices was the highest (3.25/5).

Finally, respondents with low screen time, reported the highest positive emotion (1.75/3) when their discovered the difference between their estimate and the device market value.

#### 5.2.4.2 Screen-time: descriptive statistics

When aggregating data to illustrate screen time trends, most students spend up to two hours of screen time for each segment of the day (Figure 5.3). 90% of the students spend up to 2 hours in the morning, they are 79% in the afternoon (lunch included) and 74% in the evening (dinner included).

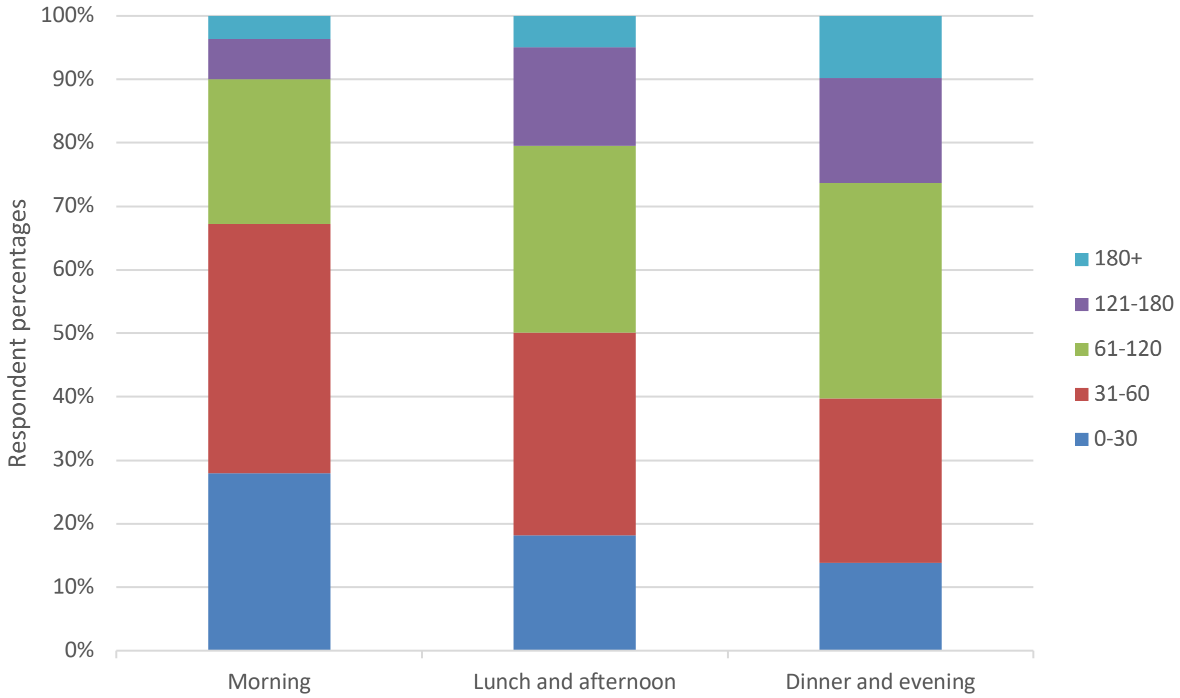



Figure 5.3 Students average screen time in minutes spent per day segmented between morning, afternoon and evening

Figure 5.4 illustrates that respondents who have reported medium (2) and high (3) screen times declared they had more mobile devices stored than respondents reporting low (1) daily screen time. Respondents with high daily screen time have 1.76 mobile stored on average, compared with 1.08 on average for respondents with low screen time.

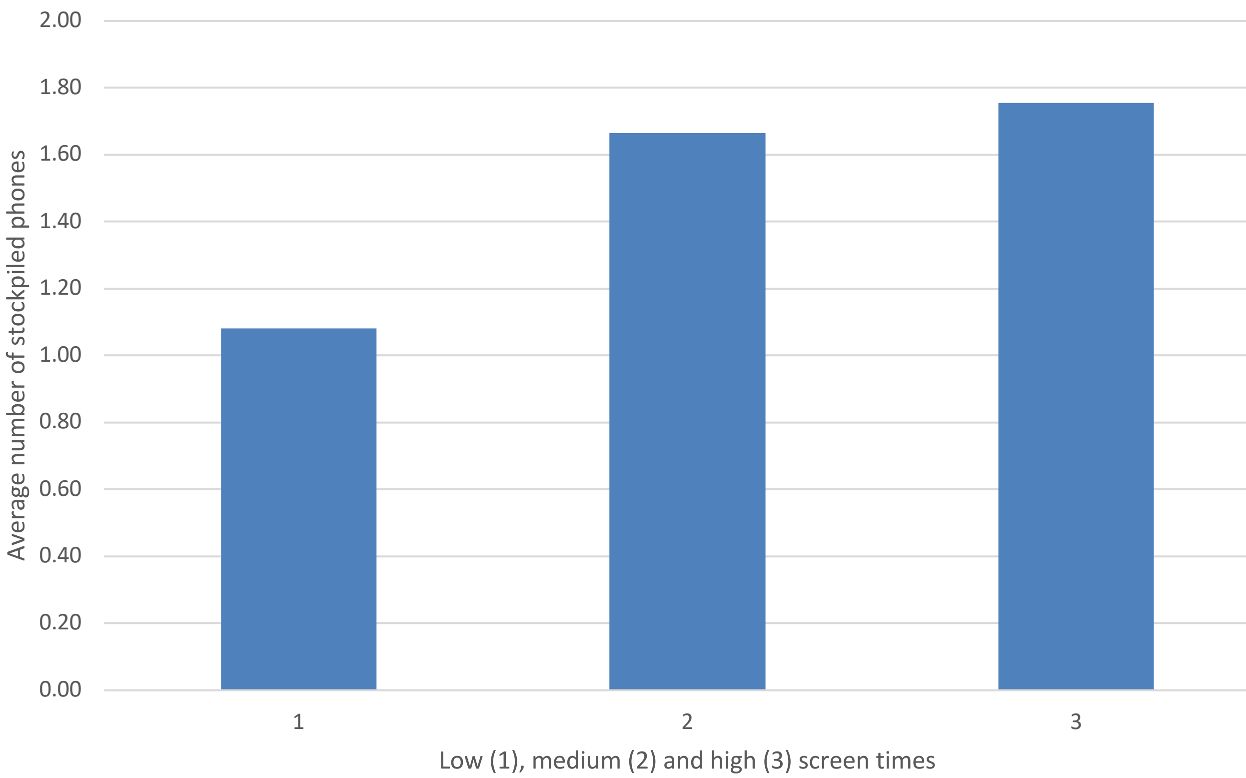



Figure 5.4 Screen time levels and number of stored smart phones

Daily screen time is a useful variable as a proxy as it is correlated with many other variables. The higher the screen time, the more expensive are the devices, the higher the utility or the more time devices were left in storage. Users with medium and high screen time tend to store more devices than users reporting low daily screen time.

**5.2.4.3 Emotions**

Figure 5.5a illustrates the emotion reported by respondents who had a positive difference between the device market value and their estimate (overestimate), for example their device is worth £250 and they approximated their smart phone was worth £135. Students expressed surprise, indifference and disappointment.

Out of 515 respondents, 464 responses for emotions reported were exploitable. Sometimes the fields were blank or the wording was out of context. Some 60% of respondents experienced a positive difference and 40% a negative difference.


Figure 5.5a: Single-word emotions mapped with word cloud software for overestimating the device secondary value

Table 5.7 highlights the mean positive difference for the three most cited emotions, in decreasing order: surprised, indifference and disappointed. Respondents citing indifference had a mean difference of £67, those with £73 were surprised and finally the highest difference at £87 felt disappointment. The mean value for positive difference is £69 (± std error £4.70).

Table 5.7 Positive difference descriptive statistics for three most common emotions

| Positive difference | Surprised | Indifferent | Disappointed |
|---|---|---|---|
| Count | 51 | 35 | 26 |
| Mean | 73 | 67 | 87 |
| Standard error | 10 | 16 | 20 |

Figure 5.5b illustrates the negative difference between devices estimated and market values (underestimate), for example when the device's estimated secondary value is lower than its market value. Students expressed surprise, negative emotion and indifference.


Figure 5.5b: Single-word emotions mapped with word cloud software for underestimating the device secondary market value

Table 5.8 highlights the underestimation between the device's estimated and market values. Estimated values were lower than the market estimate. The three most cited emotions are in decreasing order: surprise, sad or shocked, and indifference. The average negative difference for all respondents is -£101 (std error £24.70). Surprised respondents had an average difference of -£127, those who felt sad or shocked had an average of -£85 and finally students who felt indifferent reported a -£53 average difference.

Table 5.8 Negative difference descriptive statistics for three most common emotions

| Negative difference | Surprised | Sad + shocked | Indifference |
|---|---|---|---|
| Count | 85 | 27 | 17 |
| Mean | -127 | -85 | -53 |
| Standard error | 55 | 14 | 22 |

#### 5.2.4.4 End-of-use behaviour segmentation

First of all, end-of-use behaviours are defined based on the number of stored devices. Then, several metrics are associated to end-of-use behaviours to illustrate differences.

##### 5.2.4.4.1 Quantity of stored devices

Thirty seven percent of respondents declared they had no spare mobile device, 21% had a single backup device and 42% had more than once device stored (Figure 5.1). 82% of stored devices were in working order. These amounts of stored devices can be used to create categories to identify differences between them (Table 5.9). Students who have more than one device stored can be considered to have created an “exploitable stock” (Table 5.5). The results from Table 5.9 are described and contrasted from the perspective of respondents who have more than 1 stored device. Variables were selected to describe the device in current usage (mean utility, market value, personal valuation and difference between estimated and market values), the past decisions they had made with a previous device (reuse, resell, recycle, discard) and some categorical variables (gender, fee status and degree type).

Table 5.9 Stored devices as categorical variables and selected factors of interest. Data in bold highlight values for more than one device stored

| **Data** | **Factors** | **Number of devices stored** | | |
|---|---|---|---|---|
| | | 0 | 1 | **>1** |
| Mean | Utility | 7.97 | 8.11 | **8.29** |
| | Market value (£) | 130 | 120 | **162** |
| | Personal valuation (£) | 212 | 198 | **268** |
| | Estimate and market value differences (£) | -25 | 14 | **13** |

From Table 5.9, data indicate that students who have reported having more than one device stored declared having a higher average utility for the device they are currently using (8.29/10) than students with one (8.11/10) or no spare device (7.97/10). They have a mobile device that is more expensive (£162 as opposed to £120 or £130). Their personal valuation is higher as well: £268 compared with £198 or £212. The difference or measured endowment effect is positive and approximately similar to students who do not have a spare device. Students who do not a spare device tend to experience a negative endowment effect, meaning that their device’s market value is higher than their personal valuation.

To better describe the sample for categorical variables such as gender, fee status, degree type or institution of origin, percentages from Table 5.9 are compared with percentages from Table 5.3 describing the UK student population. From the statistical tests performed, only the categorical variables associated with gender and fee status can be generalised. Students with more than one device stored are 49% males, 80% of them are home/EU students and 70% are studying an undergraduate degree (Table 5.9). This compares with a UK student population composed of 43% male, 87% home-EU students and 77% studying an UG degree (Table 5.3).

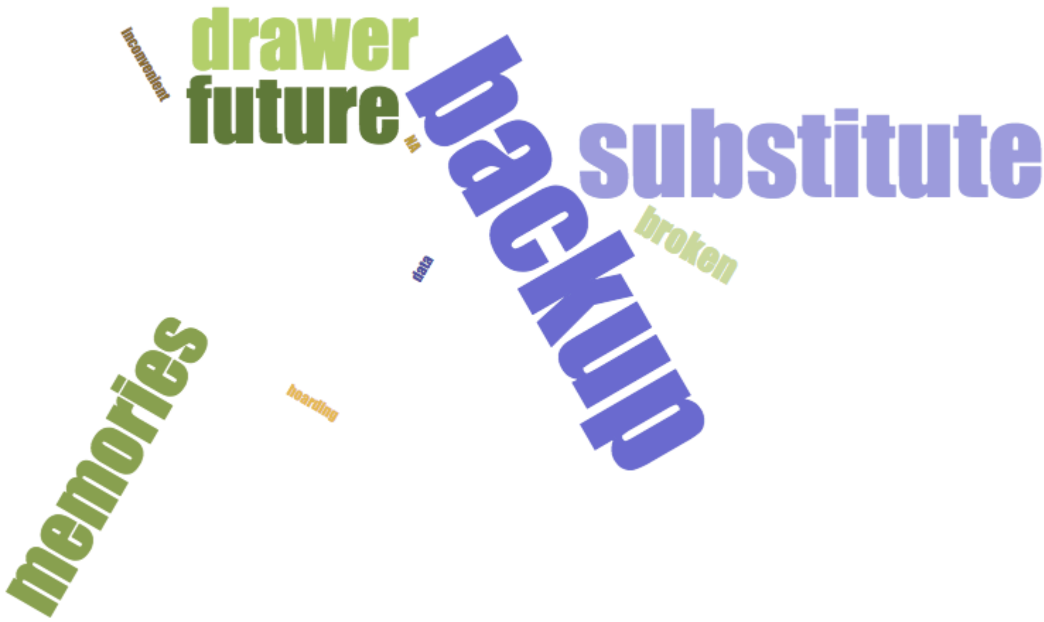



Figure 5.6 Stockpiling reasons for respondents who have only one device stored

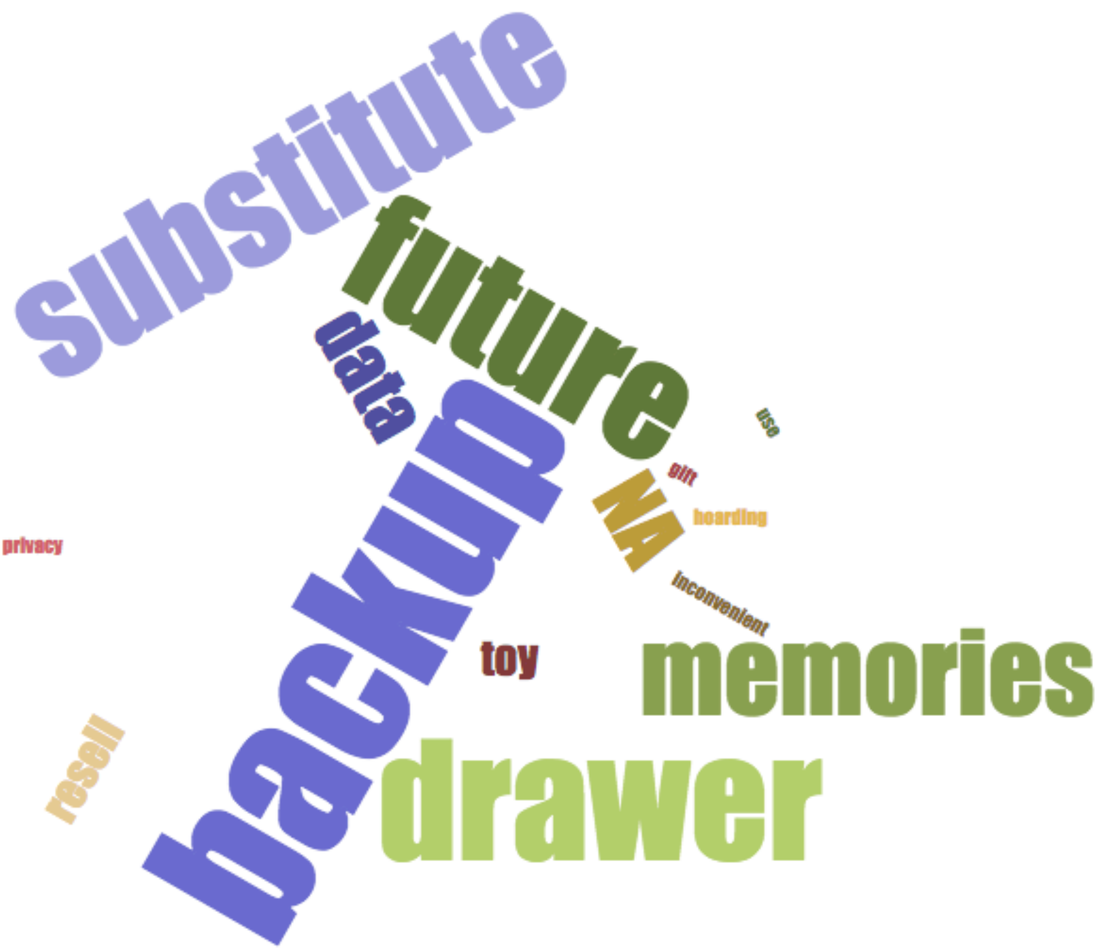



Figure 5.7 Stockpiling reasons for respondents who have more than one device stored

Reasons to store one or more mobile devices are broadly similar. The main reasons are to have a backup, a substitute or to keep it in a drawer for a future potential use (Figures 5.6 and 5.7).

#### 5.2.4.4.2 Past decisions

Profiles are based on past behaviour rather than future intentions. Respondents were asked if they had already given to a friend or family a mobile phone (reuser), if they had already sold away a device (reseller), if they had already recycled one (recycler) or if they had already discarded a mobile device in the general refuse (discarder). Respondents could select several categories. For example, 245 respondents reported they had already reused, 76 had reused and sold, 23 had reused, sold and recycled, and 6 had experienced all four alternatives.

Table 5.10 End-of-use decisions for past mobile devices. Respondents could select several alternatives

| n = 515 | Reusing | Reselling | Recycling | Discarding |
|---|---|---|---|---|
| Reusing | 245 | 76 | 23 | 6 |
| Reselling | | 108 | 26 | 4 |
| Recycling | | | 86 | 15 |
| Discarding | | | | 74 |

Based on Table 5.10 and by allocating respondents to a single category, it can be inferred that 47% of respondents have already reused a mobile they previously owned. 21% have sold it, 16% have recycled their device and 14% have discarded it in the general refuse (Figure 5.8). Six out of 515 respondents have reused, resold, recycled and discarded.

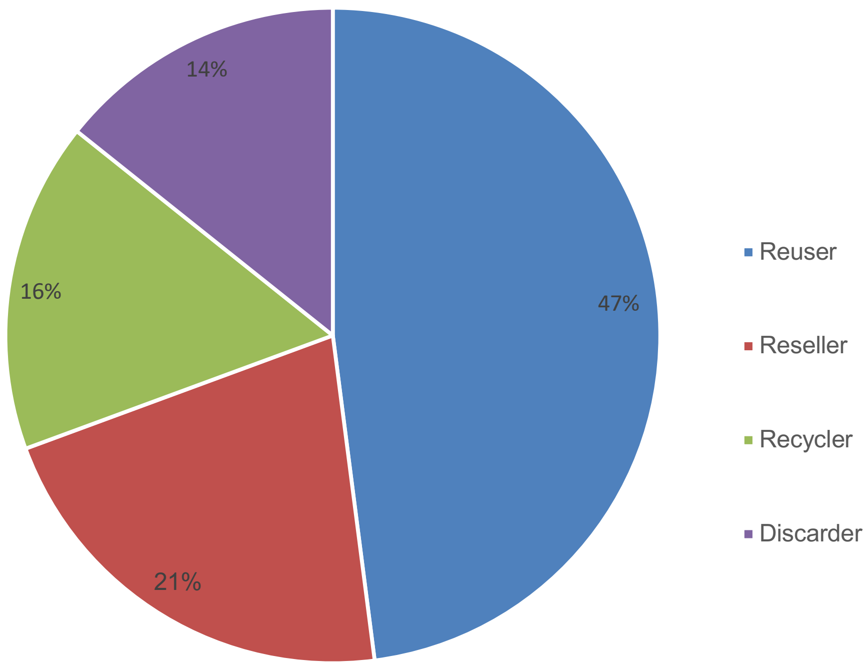



Figure 5.8 Profile distribution of survey respondents by previous end-of-use decision. Four profiles displayed: reuser, reseller, recycler and discarder

All profiles have significantly overestimated their device value (Figure 5.9). The difference between the estimated mean value of the device and the market value is £115 for reusers, £140 for resellers, £131 for recyclers and £145 for discarders. Respondents, when asked to estimate their device value when it will be replaced, gave figures close to the current market value.

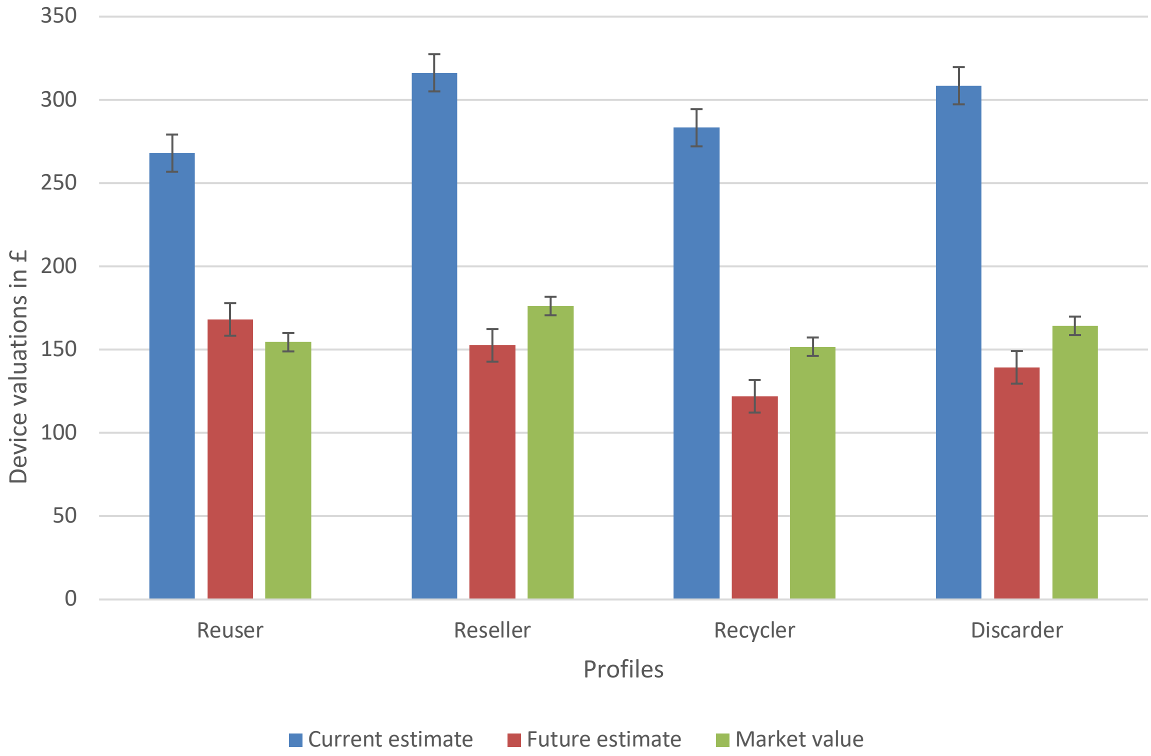



Figure 5.9 Profiles and valuation imbalances. Blue bars represent owners' current estimate, orange bars their estimate for the future and grey bars the device actual market value. Error bars represent the mean standard error for each measurement.

Table 5.11 has been compiled using profiles as categorical variables to measure their utility and the quantity of devices stored at the time of the survey.

Table 5.11 Profiles, utility, time in storage and quantity of mobile devices stored

| | Reuser | Reseller | Recycler | Discarder |
|---|---|---|---|---|
| Utility[11] | 4.56 | 4.35 | 2.6 | 1.94 |
| Quantity stored[12] | 1.74 | 1.76 | 1.38 | 1.28 |

Reusers and resellers had the highest utility for their device before parting from it: 4.56/10 and 4.35/10 respectively (Figure 5.10). Recyclers had a utility of 2.6/10 and finally discarders had the lowest with 1.94/10 when they made the decision to discard the device in the general refuse.

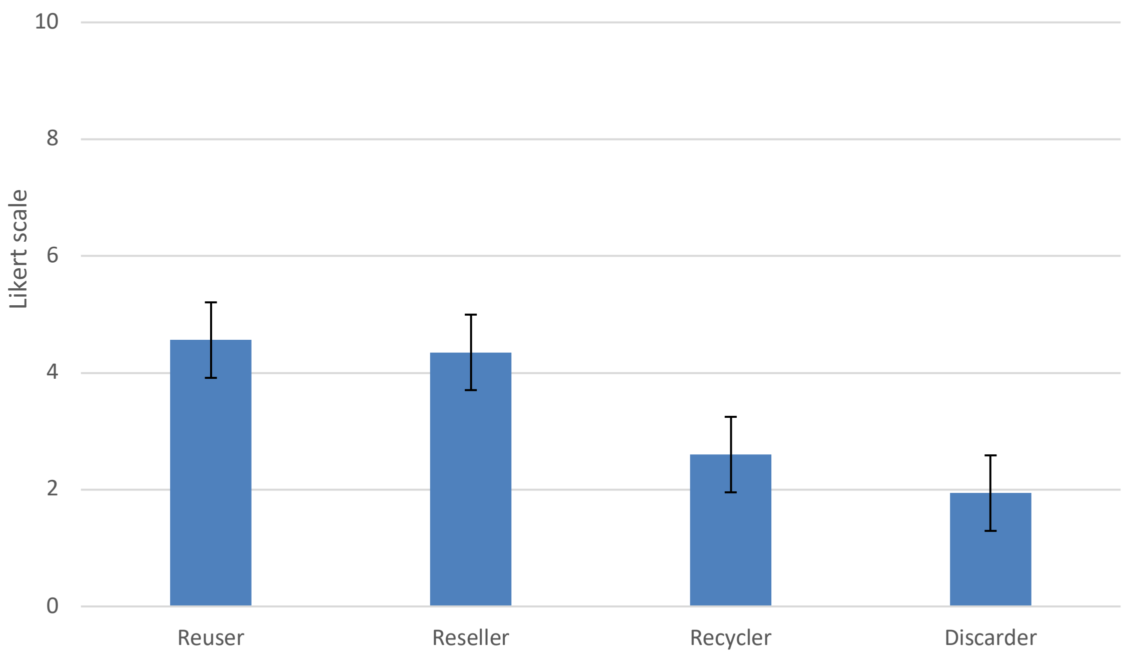



Figure 5.10. Average utility for each profile after the item had been stored away and before the end-of-use decision was taken. Likert scales ranged from 0 (no utility) to 10 (full utility). Error bars represent the mean standard error.

[11] 0 to 10 scale
[12] 0 to 4 scale

Devices intended to be given to a friend or family (reused) or sold spend the least amount of time in storage, compared with devices intended to be recycled or discarded (Figure 5.11). Some 38% of reused and 47% of resold devices spent less than a month in storage, compared with 30% and 12% for recycled and discarded devices respectively. On the contrary, devices intended to be recycled or discarded spent the most amount of time in storage: 35% of discarded devices were stored for more than 12 months and 26% of recycled devices.


Figure 5.11 Profiles and time device held in storage before a destockpiling decision was made

Reusers and resellers have the most devices stored: 1.74 and 1.76 respectively. Recyclers have 1.38 devices stored on average and discarders 1.28 (Figure 5.12).

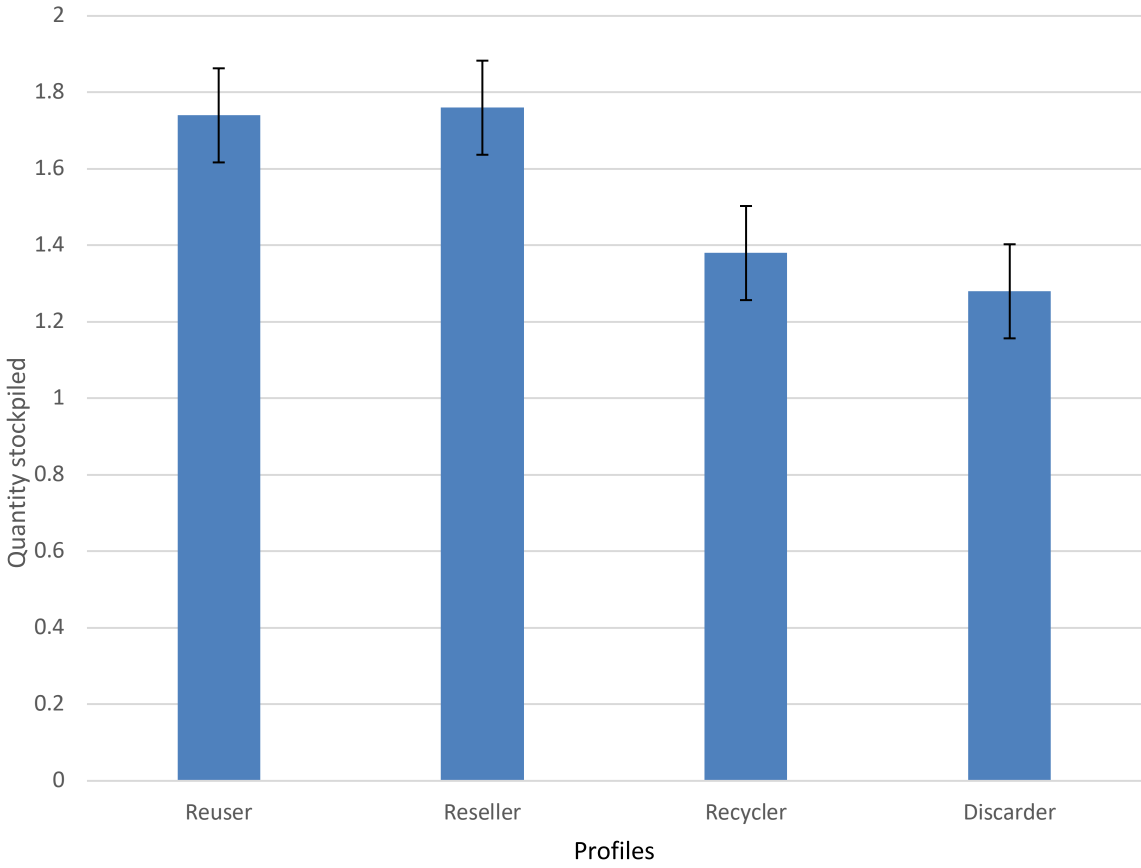



Figure 5.12 Profiles and average quantity of devices stored at the time of survey. Error bars represent the mean standard error.

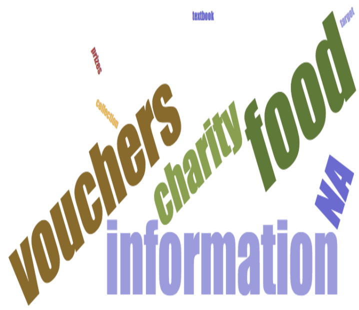
Profiles indicate wide differences in terms or phone valuations, the utility they had for their unwanted device prior to making an end-of-use decision or the time they left the device in storage prior to making this decision. Profiles showed stark contrasts for variables relative to the number of stored devices.

**5.2.4.5 Incentives**

**5.2.4.5.1 Screen time and incentives association**

Screen time has proven a reliable categorical variable: the higher the screen time, the more devices tend to be stored, the higher device value, the higher their present and future estimates (Table 5.6). Screen time is correlated with more variables than utility, gender or degree type (Appendix K). It is logical to continue using screen time as a proxy for destockpiling incentives and exploiting DUMs, especially as modern smart phone now report daily, weekly and monthly screen time. Respondents were asked to cite freely a non-monetary incentive that would trigger a destockpiling decision, such as taking an unwanted device to a convenient collection point on campus. Their responses were then aggregated according to low, medium or high daily screen time (Table 5.12).

Table 5.12 Daily screen time levels (low, medium and high) and non-monetary incentives association

| **Low screen time** | **Medium screen time** | **High screen time** |
|---|---|---|
|  |  |  |







For low screen time, the three most important non-monetary incentives are information to be provided, charity and barter. Users with reported low screen time would value having information on the benefits provided by reusing a mobile device, instead of buying a new one. This could be the amount of primary resources saved, such as water, ore etc. or the positive impact on the environment with a reduced carbon footprint.

For medium screen time, the three most important non-monetary incentives are information, food and vouchers. The non-monetary incentive associated with food illustrates that respondents appear willing to accept food incentives against their unused mobile device. Whilst this initially seems perhaps odd to trade a lasting reusable item against a perishable product, it underlines the importance to craft incentives according to intended population segments.

For high screen time, respondents expressed - in decreasing order of importance - that no incentive (none), vouchers and “experience” would be the most valued non-monetary incentives. Respondents frequently indicated that no “non-monetary” incentives could trigger a destockpiling decision. This reflects the importance a backup phone has for users declaring having high screen time. They would rather have at least one backup device if the primary device failed. Respondents indicated that “experience” was important to them. They meant they would be willing to destockpile if they could receive services or support related to their exams or coursework. Again, whilst this information seems perhaps odd, to trade a tangible item against an intangible service, this indicates that incentives do not necessarily need to be complex to influence a behaviour but need to be designed according to specific population segments. Finally, students expressed that vouchers would be a valid non-monetary incentive.

#### 5.2.4.5.2 No possible incentives

Twenty-four respondents out of 515 declared that no “non-monetary” incentives would possibly convince them to part with their spare device. These respondents insensitive to incentives tend to have high screen time (Table 5.12). Fifty percent of them have 1 phone stored and 50% have more than one device stored.

## 5.3 Discussion

This section presents an evaluation of UK universities mobile and smart phone Distinct Urban Mine; discusses how screen time influences the endowment effect; defines additional end-of-use profiles; presents a model encompassing the Endowment Effect and screen time.

### 5.3.1 Mobile devices DUM status in UK universities

This research estimates there were 3.4 million phones stored among UK students in 2016 (Table 5.5). These estimates should be viewed with caution as male and overseas students tend to be slightly over represented in the sample and the comparison made subsequently with Ongondo and Williams (2011) is based on different methodologies. Ongondo and Williams (2011) estimated that 3.7 million mobile devices were stored by students in the UK in 2010. These estimates indicate that efforts to prevent stockpiling have been partly successful. But it should be noted that there have been “austerity measures” all over Europe during this period which might have affected mobile a smart phones consumption trends. In six years, the increase of stored devices has been stemmed. Students need to have backup devices or substitutes readily available. However, having two backup devices is unnecessary. Forty-seven percent of respondents declared they hadn’t used their stored device for the intended initial purpose (Table 5.5b). Therefore, it is estimated that approximately 1 million devices could be accessed in the UK higher education system alone, for reuse, resale or recycling purposes (Table 5.5).

Stockpiling reasons remain broadly similar to past research on mobile phones. In this study, the three most important factors represent 64% of responses (Table 5.5a) and are compared with two academic sources, specifically investigating mobile phones disposal factors (Table 5.13; Ongondo and Williams, 2011; Yla-Mella, 2015).

Table 5.13 Three most important factors in decreasing order compared with selected literature

| Quantitative study (2016) | Yla-Mella (2015) | Ongondo and Williams (2011) |
|---|---|---|
| Backup purpose | Backup purpose | Backup purpose |
| Future utility | Haven't decided yet | Don't know what to do with the device |
| Future resell or future recycling opportunity | Don't know what to do with the device | Device is valueless |

The reasons are broadly similar from one study to another in this case, especially for the first factor (backup purpose). In Ongondo and Williams (2015) and Yla-Mella (2015) studies the second most important reasons is the lack of awareness, whilst in the present study respondents believed it might have a future utility. However, in less than 50% of the time, the store-away reason had not happened (Table 5.5b).

Ongondo and Williams (2011) estimated that: 77% of UK students had a spare device as a backup if the primary failed, 30% stored as they didn't know what to do with the device, 23% kept it as they believed it had no residual value left, 21% had valuable information stored and 16% planned to give it to a friend or family. There are both thus similarities and differences between the present study and that of Ongondo and Williams (2011). The three most important similar factors for both studies are the need to have a backup, limited awareness of end of use possibilities and prefer to keep the device as a spare.

In terms of differences, Ongondo and Williams, (2011) estimated that data related-issues were quite important for students. In 2016, even though more valuable data can be stored on smart phones compared with feature phones, this is less of a concern (Table 5.5a) and probably as take-back schemes offer to wipe data from collected devices. An aspect that has emerged in this study is the need to keep a spare device to access personal data, such as images and messages to remind oneself of memories (Figure 5.2). This is linked to the increased memory capacity of today's smart phones, either on device or on the cloud, compared with devices at the beginning of the present decade.

Despite the existence of the WEEE recast legislation in 2012 addressing specifically small WEEE take back (Directive 2012/19/EU), the existence of online take-back schemes and the repeated pleas of waste management scholars to communicate more on reuse, resell, recycle opportunities (Ongondo and Williams, 2011; Yla-Mella, 2015), there is still a substantial amount of small electronics in storage. As Gutierrez (2010) pointed out, the longer e-waste is stored the more likely it will be discarded in the general refuse. There is a potential of close to one million devices to be retrieved in the UK higher education (Table 5.5). To access this stock a better understanding of past behaviours for similar devices should be undertaken to establish profiles and refine efforts to collect stored away mobile devices, reduce future storing away behaviour and redirect general refuse flows into recycle streams.

### 5.3.2 Categorical variables: screen time, endowment effect and profiles

Reported screen time is a valid categorical variable as a proxy indicating significant differences for specific independent variables. Students with high screen time display the strongest endowment effect as they tend to overestimate vastly the value of their device. All profiles based on past behaviour point out differences as well in terms of time the devices are held in storage the number of devices stored.

#### 5.3.2.1 Screen time

Screen time is correlated with more independent variables than origin (home/EU and overseas respondents), age or gender (Appendix K, Table 5.6). Screen time has not yet been used in waste management studies to describe intended reuse, resale, recycling or discarding behaviour. If looking at TPB-related studies in waste management (Table 2.1), the factors frequently investigated are attitude, subjective norms, perceived behaviour control, anticipated feelings, intention, awareness of negative consequence, desires, past behaviour, local waste knowledge, gender, experience, or active concerns (e.g. Barr, 2007; Perugini and Bagozzi, 2001; Carrus et al., 2008, Wan et al., 2014; Bamberg et al., 2007). For these studies, the intention to engage in a positive behaviour for the environment was high with variance explained above 70%.

These studies show that the core TPB elements (Table 2.1) are proven reliable: attitude, subjective norm, perceived behavioural control (PBC), intention and behaviour. Therefore, the TPB should be used as the basis to produce behavioural models specific to small e-waste. In this study, it is demonstrated that screen time is a valid and useful variable correlated with a large number of other variables (Appendix K; Table 5.6). When developing frameworks or models analysing small electronics behaviour, screen time should be integrated as valid and useful behavioural variable.

#### 5.3.2.2 Endowment Effect

Table 5.6 illustrates that the endowment effect is evidenced for all screen time levels. Respondents with high and medium screen time tend to have higher device overvaluations then respondents with low screen time. The overvaluation is the difference between the device subjective value and its market value. Respondents with high and medium screen time overestimated their device's value by 63% and 72% respectively. Low screen time respondents overestimated by only 59%. These observations illustrate the endowment effect (Tversky and Kahneman, 1991) is shared among all respondents and is influenced by screen time. The endowment effect is the increase in a device valuation by the simple fact of ownership, which is clearly demonstrated in this study. The more respondents spent time with their device, the more they overvalued it compared with the market value. This overvaluation triggered then a negative emotion as users were disappointed to learn about the difference in values (Figure 5.5a; Table 5.7). This study indicates that the endowment effect and the negative emotions associated are contributors to stockpiling.

When students overestimated their device value, they were surprised, indifferent and disappointed (Figure 5.5a). When they underestimated their device, they were surprised, shocked and indifferent (Figure 5.5b). The main difference is the disappointment felt when overestimating as opposed to the indifference when underestimating. The under or overvaluations have an influence on the emotions felt. Perugini and Bagozzi (2001) used anticipated negative and positive emotions to extend the TPB into the Model-Goal Behaviour (MGB) (Table 2.1). These emotions are associated with perceptions of failure or success prior to engaging in a behaviour. It equates to associating emotions to the Perceived Behavioural Control (PBC) factors from the TPB (Ajzen, 1985). The Endowment Effect integrates valuation distortions.

Users with medium and high screen time stored more devices than users with low screen time (Figure 5.4). Higher screen time users would rather have several devices stored than engage in a reuse / resell / recycle behaviour they would not be fully content with. Therefore, the only acceptable options are reuse, resell or store. Recycling is a destructive activity and users would rather store a device in working order than destroying it; 82% of students storing away their device declared it was still in working order. The endowment effect favours stockpiling decisions. As the endowment effect is associated with monetary incentives (the device market value), relevant non-monetary incentives should be designed to overcome this barrier and trigger a destockpiling behaviour (Table 5.12).

#### 5.3.2.3 Stockpiling and hoarding profiles

A distinction has been made between students who have no spare device, those who have only a backup phone and those who have more than one device (Table 5.5, Table 5.9, Figure 5.4). Considering that students store devices to have a backup or substitute and considering that having more than one device stored can be considered as "exploitable stock" (Table 5.5), distinct profiles could be established based on the quantity of devices stored. Therefore, there should be a distinction between students who have a single stored device and those who have constituted an "exploitable "stock" with more than one device stored. It is proposed to define two different profiles based on these safety and exploitable stocks. Owners who have a single stored device are *stockpilers* and those who have more than one device are *hoarders*.

These different profiles help distinguishing between a "necessary stock" and an "exploitable stock". Furthermore, hoarders tend to have a higher utility for their device, have a more expensive smartphone or have a higher endowment effect (Table 5.9). This distinction can help to further segment and target approaches when designing methods to exploit urban mines.

All types of respondents tended to overestimate the value of their mobile device (Figure 5.9). Recyclers exaggerated by 77%, reusers by 69%, resellers by 47%, and discarders by 45%. This overvaluation demonstrates the endowment effect applied to mobile phone ownership (Thaler, 1980). Reusers, resellers and recyclers estimated their device value within a narrow range (£259 to £266). But discarders gave a much lower average value (£219). Reusers and recyclers overestimated the most and resellers and discarders the least. The endowment effect confirms that the biases influencing perceptions operate in a similar fashion as demonstrated by researchers in behavioural economics (Kahneman et al., 1990; Strahilevitz and Loewenstein, 1998; Thaler, 1980). UK students are subject to biases when framing perceptions about their mobile device. Consequently, similar biases might affect their decision-making process and explain why some devices are stored and are not being in use.

Reusers keep their device in storage the longest (Figure 5.11). In contrast, resellers tend to keep their device for a short period of time. Resellers have an incentive to rapidly resell their device as the longer it will be in storage, the more value the device will lose. Reusers are not bound by the same market principles as they intend to give the device to a friend or family. Although Ongondo and Williams (2011) estimated that close to 19% had reused and more than 8% had sold away or traded them, they didn't estimate the amount of time the devices were stored away. Reusers and resellers have the highest quantity of devices stored on average. In addition to their safety stock, they might have a future intention to give or resell another device in the future.

Discarders tend to keep their device in storage for a longer compared with recyclers (Figure 5.11). Discarders might unsuccessfully attempt to explore alternatives to dispose of devices before they finally consider the burden of keeping them superior to the potential guild associated to throwing them in the bin. The high storage time value is in line with Gutierrez et al. (2010) who estimated that the longer in storage, the more likely the device will be discarded. Discarders and recyclers have the lowest number of stored phones on average (Figure 5.12). Once they decide to recycle or discard, they might do so in bulk and get rid of several devices at once, especially if recycling points are considered inconvenient (Ongondo and Williams, 2011). This could result in a higher discarding rate. When a decision is taken to reduce the existing stock by discarding in the general refuse or going to a recycling point, several devices are "dehoarded" at once. Which could explain the lower quantity of devices stored for discarders: 1.28 on average as opposed to 1.74 on average for reusers (Figure 5.12).

Some 86% of students have already engaged in activities positive for the environment, as they have reused, sold away or recycled unwanted mobile devices (Table 5.10, Figure 5.8). However, despite having already reused, sold or recycled, students still store many devices (Table 5.5). After backup reasons, still many students do not know what to do with them or have not decided yet. Perez-Bellis et al. (2014) noted that the longer a device is stored the more likely it will end up in the general refuse. This might be especially true for mobile and smartphones given their small size. Another factor at work in the stockpiling decision-making process is the endowment effect. Respondents with low, medium and high screen time overestimated the value of their device (Table 5.6), as well as all profiles (Figure 5.9). This recurring and consistent overvaluation could be an explanation why some students are not reselling unused devices; despite the fact they have already used these services. The lower than expected monetary reward acts like a barrier to put back a device in working order into the second-hand or refurbished market. Non-monetary incentives should be added to existing monetary incentives to overcome this barrier.

### 5.3.3 Incentives: segmentation

Screen time is a valid categorical variable to segment incentives. Incentive segmentation is useful to target certain type of users and propose incentives that would increase their intention to “dehoard”.

Segmenting incentives as per the estimated screen time yielded significant differences (Table 5.12). Low screen time users would prefer non-material incentives, such as information or charity. Medium screen time users would prefer information or food. High screen time users estimate that no non-monetary incentives would trigger a destockpiling behaviour or they would want to have vouchers.

It was surprising that students cited a perishable item such as food as a prominent choice for non-monetary incentives. But this shows that non-monetary incentives do not need to be highly complex to be effective if they are targeted precisely (Table 5.12). Ongondo and Williams (2011) found that cash was the preferred incentives to trigger a reuse or recycle behaviour. It should be noted at that time the European Union was in a difficult economic situation due to the “Great Recession” (OECD, 2018). Yla-Mella (2015) estimated that a deposit of 5 EUR would be appropriate to trigger a reuse or recycling behaviour for mobile phones, but this estimate does not consider the device’s monetary value and could only be applicable to devices that have a second-hand market value equal to or less than 5 EUR. In the present study, respondents were asked which non-monetary incentive they would be interested in. Each profile did have a different order of importance but the categories remained the same. UK students would be interested in having access to vouchers.

These vouchers would provide discounts or access to a variety of items they would be able to choose from a selection. Ongondo and Williams (2011) found vouchers as the second most popular incentive among UK university students. Ease of use and convenience were ranked third position and fourth position respectively in their study. UK students would like to barter their unwanted device against accessories for their current smart phone, for example protection screens or protection cases (Table 5.12). Ongondo and Williams (2011) identified that students were keen to have airtime or ringtones to enhance their device, but this was ranked low in their preferences for incentives. Information was often cited (Table 5.12). UK students would be interested in knowing more about what happens to their phone once they part from it. They would like to be informed of the benefit to the environment a reuse action generates for the planet. They cited they would be eager to give away their phone for charitable purposes and would welcome being able to choose the charity. Ongondo and Williams (2011) estimated that environmental concerns and charity would be relevant incentives to trigger this behaviour.

A wide range of incentives has been tried and tested, from prepaid phone cards to tree planting (Tanskanen, 2013) with mixed results as still less than 15% of mobile phones are recycled in developed countries (MacArthur Foundation, 2015). Moreover, approximately 140 million units have been reused in 2016 (Deloitte, 2017), compared with 2.7 billion that have been manufactured in the same year (Gartner, 2017). Baxter and Gram-Hanssen (2015) advocated the use of different techniques by better framing end users' decision paths when deciding to part from their device. It is proposed that future efforts to prevent stockpiling and "destore" existing devices should incorporate monetary incentives and non-monetary incentives into a single solution. The aim is to improve existing incentives and reduce existing barriers to increase reuse, resale and recycling rates. Take Back Schemes could review their incentive schemes based on these findings and use models adapted to small electronics to enhance their collection systems.

### 5.3.4 Proposed model to exploit small e-waste urban mines

Based on the TPB (Ajzen, 1985), a model explaining the gap between end-of-use intentions and behaviour is proposed (Figure 5.13). It is suggested the endowment effect (Thaler, 1980; Tversky and Kahneman, 1991) is at work between intentions and behaviour. Users tend to overvalue their device compared with market values and would rather keep the devices as backups, rather than engaging in an "unfair" transaction. The endowment effect is a function of screen time; the higher the screen time, the higher the device overvaluation (Table 5.6) and the higher the number of hoarded devices (Figure 5.4).

The potential end-of-use behaviours are to resell, to give away, to recycle, to discard or to store. The TPB is a valid basis to create a model attempting to explain end-of-use decision-making for small electronics (Table 2.1; Figure 5.13). From the statistical analysis performed (Table 5.6), screen time emerged as function of the endowment effect. The higher the screen time, the higher would be the device overvaluation. This subjective valuation compared to the device second-hand market value, triggers negative emotions (Figure 5.5a), which in turn could explain the weakness between intention and end-of-use behaviour, which sits in the TPB frame (Table 2.1). The endowment effect appears to prevent users from reselling; they would rather keep the device for a potential later use. Users who still have some utility for the device, might give it away to a friend or family (Figure 5.13). Lack of convenient systems to collect the phones prevent them from recycling, and discarding options are sometimes considered but rarely implemented (10 to 15%

are discarded but after a significant amount of time; Gutierrez et al., 2010; Ellen McArthur Foundation, 2012). Therefore, the default option (Kamenica, 2012) is to “do nothing” and store the device.

End-of-use decisions are to resell, give away, recycle or discard. Based on the stockpiling and hoarding activities, alternative decisions associated to destockpiling and dehoarding can be added to the pallet of choices (Figure 5.13). One direct consequence of the weakness between the reuse intention and the absence of behaviour, is hoarding, i.e. when more than one device is stored away. Besides, having one device as backup is stockpiling and having more than one device is hoarding. Between one and twelve months, depending on the intention to resell, give away, recycle or discard (Figure 5.11), the user will again have the opportunity to destockpile or “dehoard” (Figure 5.13). Hoarded devices represent a DUM than can be characterised by the quantity of devices stored away and the time they have been held in storage. Better understanding of DUM characteristics, such as the reasons why the devices have been hoarded, should help in devising methods and techniques to exploit this stock. Reducing or countering the barriers that have led to hoarding behaviour could be more precise and targeted.

After time in storage, the user’s utility for the device will have declined, as it will have been left unused, as well as its monetary value on the second-hand market. If the resell option was not chosen immediately when the device was replaced, there is no objective reason why it should be done later in time. The reduced resale value in itself being a disincentive. The give-away option might still be considered, if the device is not obsolete. If the recycling option was not considered initially, possibly as the device is still working, there is no point to recycle it now. A similar conclusion would be reached for discarding. Therefore, the device(s) will remain in storage until the next end-of-use intention to dehoard. At each iteration, the utility the user has for the devices decreases as the device obsolescence increases, making it the less likely it will be captured by a collection system and the more likely it will eventually be discarded in the general refuse (Gutierrez et at., 2010; Perez-Bellis, 2015).

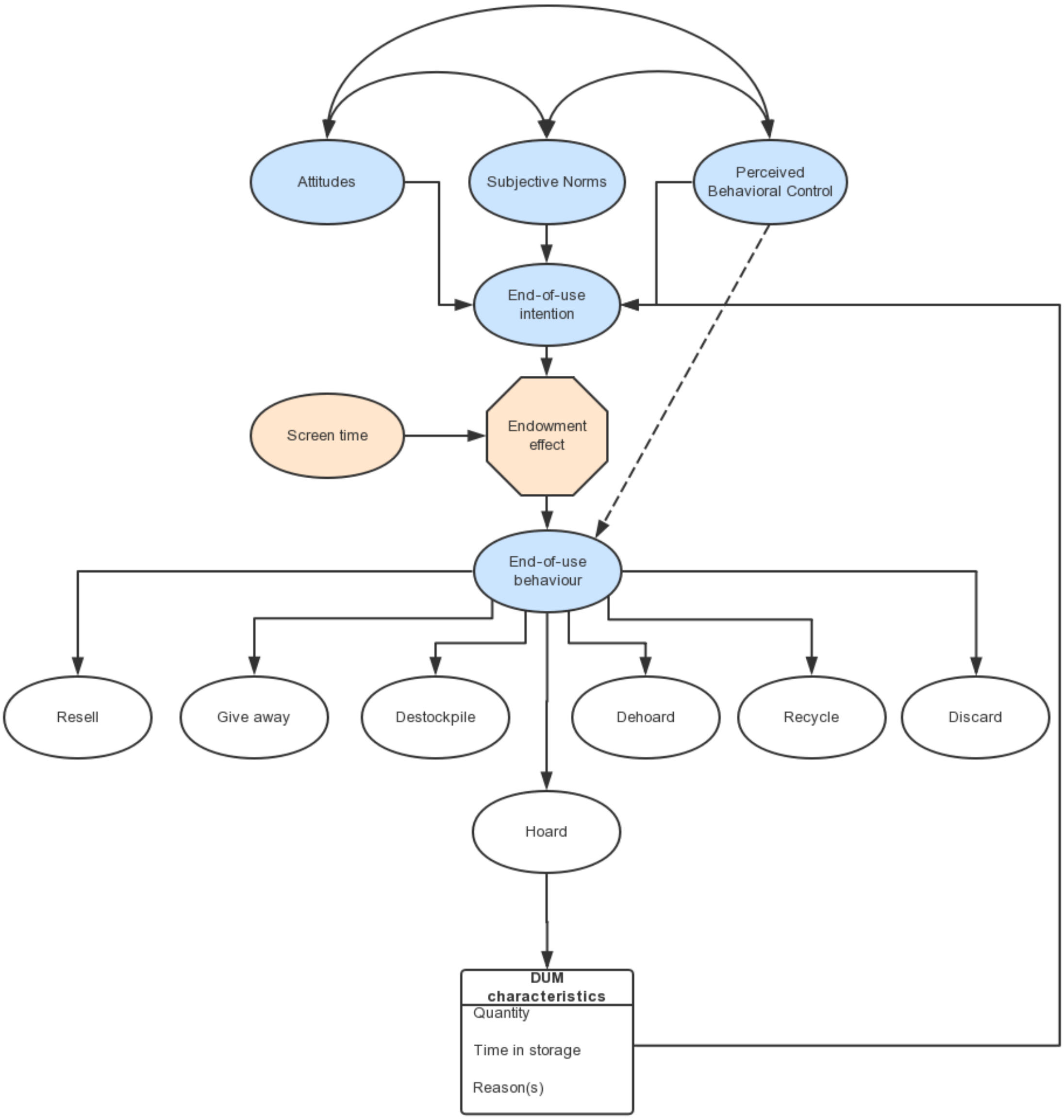



Figure 5.13. Small electronics DUM generation model – A Model of Endowed Behaviour. The TPB elements are showed in blue and the elements stemming from the data collection are in orange. End-of-use alternatives are illustrated in white. Hoarding decisions result in DUM generation

Mobile and smart phones, used as a case study for small electronics, are a good example of the circle in which these devices become entrapped due to the endowment effect and the declining utility users have for them.

## 5.4 Chapter conclusion

A Theory of Endowed Behaviour has been proposed. This model uses the TPB, the Endowment Effect and screen time as a behavioural variable to illustrate barriers for end-of-use alternatives for small electronics. The Endowment Effect has been recognised as having an impact on the quantity of stockpiled devices. The Endowment Effect is function of the behavioural variable screen time. Furthermore, a definition has been proposed to differentiate stockpilers who have a backup device for a purpose and hoarders who have several devices without a specific purpose. These definitions, as well as the Endowment Effect, are correlated to screen time. The higher the screen time spent daily, the higher the device overvaluation and the more likely owners will hoard devices. Therefore, the number of hoarded devices (HD) is function of screen time (ST) and the endowment effect (EE). It may be represented as $HO_{ij} = f(ST\alpha, EE\gamma)$.

This behavioural factor is more than just illustrating a device valuation and a past behaviour, it is the link between present and past behaviour. In addition to that, UK Higher Education mobile and smart phones DUM has been estimated at 3.4 million devices. Close to 1 million devices from this DUM are deemed as “exploitable” as hoarded away without particular reasons. A limitation should be pointed out. As previously noted, the sample over represented males and overseas students.

This is the first time the Endowment Effect has been demonstrated in relation to (W)EEE. TPB-related models mostly focus on intentions and the translation into behaviour remains weak (Carrus et al., 2008; de Leeuw et al., 2014). Screen time is a current behaviour factor that can be linked to past behaviours, such as stockpiling or hoarding, therefore reinforcing the intention / behaviour relationship. These findings have confirmed the validity to use Behavioural Economics principles this for waste and resources management. Then, there have been only limited attempts to use TPB-related models for electronics (Le Hoang et al., 2013; Xu et al., 2014; Nduneseokwu et al., 2017; Vassanadumrongdee et al., 2018), mostly in developed countries and none for specifically small electronics. Finally, Previous DUM estimates didn’t distinguish between different types of stock. This approach should help targeting efforts for DUM exploitation.

Future research could investigate the influence of a central behavioural factor such as screen time for small electronics on other Behavioural Economics principles such as the Status Quo Bias or Loss Aversion (Kahneman and Tversky, 1991). Improved collection systems for DUM exploitation could integrate the Endowment Effect and focus on reducing the Endowment Effect.

# Chapter 6: General Discussion

This chapter critically discusses and evaluates results obtained from the literature review (Chapter 2), the qualitative data collection (Chapter 4) and quantitative data analysis (Chapter 5). The chapter aim is to critically discuss the influence of behavioural factors on small electronics storing away decisions; by designing a framework based on the Theory of Planned Behaviour to recognise and prevent mobile and smart phones hoarding (§6.2.1); by proposing a method using Choice Architecture to exploit small mobile and smart phones Distinct Urban Mines (§6.3.1).
The discussion provides a new understanding of behaviours relating to hoarding of mobile and smart phones devices by exploring the impact(s) of the endowment effect and how it may be mitigated. The anticipated implications and applications for the waste and resource management sector, local and national governments, policy-makers and small electronics producers are presented.

Prior to critically discussing the conceptual framework aimed at improving small electronic collection rates such as mobile and smart phones, the main points from chapters 2, 4 and 5 are brought forward to clearly identify which results have been integrated and discussed.

## 6.1 Conceptual framework: background

### 6.1.1 Mobile and smart phones volumes

Close to 2 billion mobile devices were shipped in 2017 (Gartner, 2018) and 120 million used handsets were resold in 2016 (Deloitte, 2017). Although between 2015 and 2016 the second-hand market grew by 50% from 80 to 120 million units per year (Deloitte, 2017), there is still an immense gap to bridge to increase the number of second-hand mobile phones in regular use to maximise resource productivity. The loop is still widely opened and more efforts are necessary to gradually close it and tend towards a circular economy.

Estimates indicate that approximately 20% of e-waste is recycled (United Nations University, 2017). Other studies suggest that approximately 15% of mobile devices are discarded in the general refuse (Ellen MacArthur Foundation, 2012). The remaining devices are stockpiled or hoarded (Ongondo and Williams, 2011; Table 5.5). With more people being connected to the Internet and the gradual increase of virtual assistants from Amazon, Google or Apple (Markets and Markets, 2018), there is a major environmental cost associated with producing new devices and a lost opportunity if these devices are not eventually reinserted into the economy, either by being given away for reuse, sold for reuse, traded-in, sold for reuse of selected components and the remainder recycled.

### 6.1.2 Impacts of the WEEE recast

Despite the WEEE recast in 2012 (Directive 2012/19/EU), the number of stockpiled devices in the UK higher education system has remained relatively stable: 3.7 million in 2011 (Ongondo and Williams, 2011) and 3.4 million in 2016 (Table 5.5). To date, the introduction of this enhanced legislation, with its explicit focus on small electronics, appears to have had a limited impact on widespread hoarding of devices in the higher education sector. Young adults such as students represent current and future consumers. The habits they develop today will likely become the trends of tomorrow's society. Hence, the focus on students in this study.

Legislation requires EEE producers to take-back for free like-for-like unwanted devices (Directive 2012/19/EU). However, for devices retaining a residual monetary value, users can sell their devices to Take-Back Schemes as an alternative. The monetary income they can offer is determined by a device's second-hand market value, influenced by its cosmetic appearance and any potential / necessary repairs. But there is a gap between the legislation and the market as illustrated by the quantity of hoarded devices (Table 5.5, Figure 6.1): if the legislation were fully effective, there would not be any hoarded devices as the devices would be traded-in, sold or given away for reuse, or recycled. Therefore, a novel approach bridging the gap between contractual obligations and market principles is necessary. Section 6.2.1 proposes a framework based on the Theory of Endowed Behaviour (Chapter 6) and the behavioural incentives required to exploit a Distinct Urban Mine composed of small e-waste.

### 6.1.3 Limits of current behavioural models for small electronics end-of-use behaviour

Models used to analyse end-of-use behaviour, and more especially for small electronics, haven't yet identified a set of common factors consistently explaining behaviour. The TPB (Ajzen, 1985) is commonly used in waste management-related studies and variance explained ($R^2$) ranges from 0.22 to 0.68 for intention and from 0.08 to 0.59 for behaviour, when it is reported (Bamberg et al., 2007; Swami et al., 2011; Huffman et al., 2014; Wan et al., 2014; Table 2.1). Armitage and Conner (2001), in a wide-reaching study on TPB effectiveness, determined that this model explained on average 39% of intention and 27% of behaviour. The TPB is commonly used in Waste Management studies to explain household recycling behaviour and factors are added to increase the level of variance explained (Table 2.1). Such factors include environmental values, altruism or demographics (Hopper and Nielsen, 1991; Davies et al., 2002; Richetin et al., 2010; Ojedokun,

2011; Chan and Bishop, 2013; Pakpour, 2014; Wan et al., 2014; de Leeuw et al., 2014). Aside the TPB core elements (attitude, subjective norms and perceived behavioural control), there appears to be no set of additional common factors agreed by waste management researchers as important contributors to the predictive power of the TPB (Table 2.1).
The TPB-based current models might not be ideally tailored to small electronics end-of-use behaviour as most of these studies are based on household recycling behaviour. There are a very limited number of studies associating the TPB and electronics end-of-use (Echagaray et al., 2017; Lizin et al., 2017) exploring small e-waste end-of-use behaviour, making it difficult to identify a set of factors that could be of interest, beyond the TPB core variables (Attitude, Subjective Norm, Perceived Behavioural Control, Intention, Behaviour). However, a set of publications was identified as they consistently reported higher than usual variance explained for intention (Table 2.1, Figure 2.5).

To achieve a higher level of explained variance, thereby a better predictive power and application of the model, Perugini et al. (2001) added anticipated emotions (negative and positive), desires and past behaviour (frequency and recentness) to the TPB. Results obtained for $R^2$ were 0.76 for intention and 0.30 for behaviour. They named this new set of factors in combination with established TPB elements the Model of Goal-directed Behaviour (MGB). Initially created for a study on body weight regulation, Carrus et al. (2008) applied the MGB to household waste recycling. They reported a $R^2$ of 0.82 for intention but did not report on behaviour. Bamberg et al. (2007) used anticipated feelings in a TPB-related study on public transportation and reported $R^2$ of 0.9 for intention and 0.8 for behaviour (Table 2.1).

The TPB and the MGB with the specific use of emotions are potentially appropriate models for investigating small electronics end-of-use intentions and stockpiling / hoarding behaviour (Table 2.1). Emotions and decision-making biases have already been integrated into Behavioural Economics principles, such as the Endowment Effect or the overvaluation of object owned by individuals (Thaler, 1980). The Endowment Effect is influenced by other behavioural economics principles, such as Loss Aversion (Tversky and Kahneman, 1991) and *Status Quo* Bias (Samuelson and Richard, 1988). Loss aversion is the anticipated dislike of a potential future loss and the *status quo* bias is the default option set to a non-action. Illustrated by mobile and smart phones, the default option for owners is to not reuse, not recycle, not resell and not discard, which leads to hoarding the device for a potential later reuse or other fate (Table 5.5b, Table 5.10). If the endowment effect, with loss aversion and the *status quo* bias, influence actions regarding small electronics, this could explain why a high number of devices are stockpiled or hoarded (Table 5.5).

The Delphi study (Chapter 4) has demonstrated that “classic” waste management factors such as environmental or ethical values that have attracted attention in the literature are not necessarily relevant to small e-waste end-of-use decisions (Table 4.6). These factors were strongly dismissed by the Delphi study panel. On the contrary, the study resulted in the selection of factors related to device characteristics, such as its size, and factors associated to user preferences, such as time in storage and utility, should be considered (Table 4.7).  User preferences and device characteristics are the expression of owners’ mobile device choice and usage. This focus on technical as well as individual characteristics, closely associated to mobile and smart phones, is a step forward to designing enhanced collection methods for these devices. These factors are relevant to small electronics such as mobile and smart phones. Their small size implies convenient storage possibilities. They can be stored away for a significant amount of time depending on the utility owners have for them. The concept of utility is central to behavioural economics and can quantify quantitatively user preferences (Samuelson and Zeckhauser, 1988).

#### 6.1.4 Screen time and its influence on the Endowment Effect

Following Behavioural Economics Principles and the Delphi results, it was assumed initially that utility would be the most useful proxy. Utility is a central tenement of Behavioural Economics and it was logical to investigate this concept for mobile and smart phones. But screen time is a more valuable factor when used as a categorical variable, being correlated with more variables than utility, age or gender (Table 5.6, Appendix L). These variables shouldn’t be ignored when developing models adapted to mobile and smart phones. But screen time should be included to obtain higher variance explained for intention and behaviour. Owners with high screen time had more expensive devices, reported a stronger endowment effect, had more data stored on their mobile device, spent more money monthly for air time / data consumption, and have more devices stored. Screen time is therefore a proxy to utility.

Applied to mobile and smart phones, the endowment effect is a function of screen time and has been connected to the TPB to explain stockpiling / hoarding behaviour to create the Theory of Endowed Behaviour (Figure 5.13). The endowment effect is the positive difference between a device’s (perceived and subjective) estimated value from a user’s perspective (building on Thaler, 1980) and the same device’s (objective) market-based value. The endowment effect is stronger for users who report higher screen time (between 5 and more than 9 hours daily) than for users who report medium (between 3 and 5 hours daily) or low screen times (between 1.5 hour and 3 hours daily) (Table 5.6): users with high screen time overestimate on average their device by £118, users with medium screen time by £110 and those with low screen time by £64.

### 6.1.5 Stockpiling and hoarding activities

Users with high screen time reported more devices stored away. A distinction can be made between stockpiling and hoarding, based on the number of devices stored away. Owners who stockpile may be defined as users who have a single phone stored and have made a thought-through decision to store the phone for a reason (Table 5.5). This device may be used as a back-up if the primary phone fails or may be used as a replacement when participating in certain social events (e.g. going to a music festival) – a deliberate decision is made so as not to risk damage or loss of the more valuable device (Figure 5.2, Table 5.5a). Stockpiled devices have a specific purpose and will not enter into the circular economy at this stage as users will not part from them since they have a specific purpose as a back-up device.

However, users who have more than one device stored may be defined as hoarders. These additional devices only have a marginal utility, compared with the back-up phone. Hoarders have one device stockpiled that could be used as back-up or spare but also additional devices that don’t have any specific use (Table 5.5). They are still in working order; owners do not know what to do with them and consider they might have some use in the future (Figure 5.7). These devices are hoarded as owners are unsure what to do with them and the collection methods offered are perceived as too cumbersome (Ongondo and Williams, 2011; Figure 5.2, Table 5.5a). Hoarding could be associated to a “non-decision”. A decision to not reuse, not trade-in or not recycle.

With the influence of the endowment effect, they believe it is worthwhile keeping them rather than reselling them at a value lower than expected. Stockpilers have a specific purpose for the one device they have stored. Hoarders have a precise purpose for the most recent device, but are unsure what to do with the rest. They hoard them as they believe it might have a use in the near future or collection methods are deemed inconvenient (Ongondo and Williams 2011). Stockpiling has a specific purpose for the device but hoarding is a non-decision to avoid loss aversion and maintain the *status quo.*

### 6.1.6 Mobile and smart phones Distinct Urban Mines

A DUM incorporates an aggregation of all stored-away devices, including both stockpiled and hoarded. A DUM is dynamic in nature; devices that used to be stockpiled become hoarded when they fall into second position in storage. This is the “tipping-point” identified by Ongondo and Williams (2011). Older devices at the “bottom of the pile” are the ones that have been held the longest in storage (Figure 5.11; Figure 6.1). Some of the devices within the DUM are traded-in, recycled, discarded or simply held in storage (Figure 5.13). Therefore, a DUM is characterised by the quantity of devices it contains, but also by the quantity of devices per owner, the time these devices have been held in storage, and perhaps as importantly, why they have been hoarded (Figure 5.2, Table 5.5). Indeed, understanding why these devices have been hoarded can help improve collection methods and incentives to "dehoard". Methods to exploit existing DUM should take into consideration the "tipping point" (Ongondo and Williams, 2011) between stockpiled and hoarded devices. Stored devices' purpose evolves over time between intended use and unintended non-use. Therefore, the focus to exploit Distinct Urban Mines should be on hoarded devices, not stockpiled.

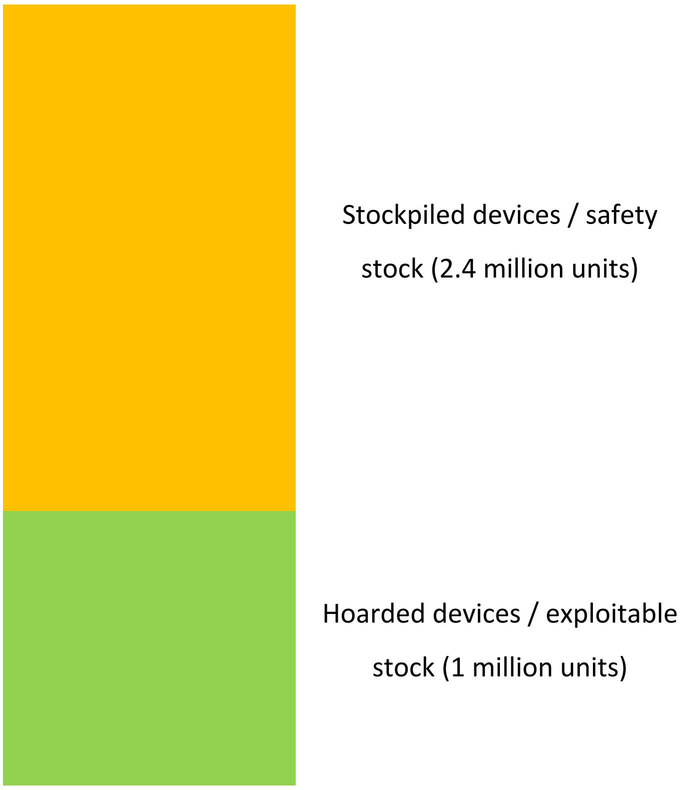



Figure 6.1: UK Higher Education DUM composed of stockpiled and hoarded mobile and smart phones representing safety and exploitable stocks (Table 5.5; 2016)

The difference between hoarding and stockpiling can bring further insights. From a waste and resource management perspective, stockpiling can be characterised as "safety stock" and hoarding as "exploitable stock". Stockpilers build up a safety stock of back-up devices having a specific purpose. Hoarders represent an exploitable stock of secondary devices that do not have a clear and immediate purpose (Table 5.5, Table 5.5a), except perhaps the most recent one used as a back-up. On the other hand, exploitable stock is built up by hoarders. Most stockpiled devices should be accepted and it should be recognised that a significant share (40%) of young adults do not stockpile or hoard (Table 5.5). This perspective can help prioritise efforts to counter the endowment effect: to prevent stockpiling and then to exploit existing DUMs composed of hoarded devices. Stockpiling and hoarding are activities that happened in the past and can only be assessed retrospectively by collecting data from owners and specifically inquiring about the number of devices stored. It would be useful to connect these activities with users' current behaviour. The current behaviour could be estimated using behavioural factors that are easier and more convenient to measure, such as screen time. Screen time can be measured by dedicated apps or reported by owners based on their estimates. Owners with low screen time tend to stockpile and users with high screen time tend to hoard (Figure 5.4).

As a result, screen time can be used as a proxy to segment stockpiling and hoarding profiles. This approach connects with the observation that factors used to explain non-recycling or non-reusing behaviour for small electronics are related to user preferences and device characteristics (Figure 4.6). Screen time is associated with user preferences as it is defined by the time users spend on their mobile device. It is also combined to devices' characteristics. The amount of time users will spend on their device depends on the device screen size, processor power, battery life and memory capacity.

Furthermore, with each new model, smart phones have more features than the previous generation such as enhanced storage capacity, larger screens, longer battery life or more performant processors. In turn this could imply a reinforced endowment effect as owners are able to spend more time using them and for an enhanced range of purposes. Evidence of this effect is provided by owners who reported higher screen time typically had devices that were more expensive and had higher memory capacity (Table 5.6).

The endowment effect is a decision-making bias having an influence on the number of devices stored away. Screen time can be used to approximate the endowment effect. Small e-waste collection systems could take into account this behavioural economics factor to improve their collection incentives.

## 6.2 Conceptual framework to prevent hoarding, exploit distinct urban mines and tend towards a circular economy

Considering the Theory of Endowed Behaviour as an element of the conceptual framework, this study suggests two progressive stages to close the circular economy loop further and increase collection rates of small electronics. The first step is to recognise the Endowment Effect in relation to hoarding decisions. It acts as a barrier to end-of-use decisions participating to devices accumulation in DUMs.  Then, the second step is to exploit small electronics Distinct Urban Mines with Choice Architecture. Once the barriers are identified, actions can be taken to reduce and prevent them. This staged approach is recommended as to ensure the gradual and robust build-up of processes to initially prevent hoarding decisions, then to exploit existing DUMs.

#### 6.2.1 Recognising the Endowment Effect to prevent hoarding / Stage 1

Most young adults appear to use a contract to acquire their mobile device and a majority of those who participated in the surveys have a 24-month contract (§5.3.2; Table 5.4) and 40% of young adults in the higher education sector claim not to have a backup device (Figure 5.1, Table 5.5). The contract renewal contact point could be used by small electronics producers to capture end-of-use mobile devices. They could prevent hoarding by offering to buy back immediately an end-of-use device when owners renew their contract and / or buy a new device. Most of consumer phones are owned but if using a lease, there would a shift towards services rather than product, making the recover y of end-of-use devices more convenient. This aspect is further discussed in chapter 7 recommendations. Only half the time are stockpiled or hoarded devices used for their intended purpose (Table 5.5b) and are rather kept for unclear and uncertain reasons (Figure 5.2, Table 5.5a).

From the owners' perspective, in a rational decision-making context, the decision to part from an end-of-use electronic device would be taken immediately, as delaying the act reduces a device's second-hand value as time progresses. There may be some exceptions; certain electronics can become antiques in due course, such as the first Apple computer, as they become iconic and rare. This process is quite unusual and takes a significant amount of time. The end-of-use decision-making process is not a rational process and many subjective elements have to be considered to understand fully end-of-use behaviour (Table 2.1), such as the endowment effect (Table 5.6). The endowment effect generates anticipated negative emotions and users are inclined to keep a device as a spare, even if the primary product has a limited chance of failing and the spare device is rarely used for its intended purpose (Table 5.5b).

To transition towards a circular economy, small electronics producers such as corporate entities selling mobile and smart phones to consumers could transform their business-to-consumer (B2C) strategy to develop a new vision that is beneficial to society in general.  The triple bottom line (TBL) (Elkington, 1994) approach has been defined as the pursuit of three simultaneous goals: Economic, Social and Environmental. The TBL aims at focusing business, stakeholders and the environment, at the same time. From a business perspective, it might be counter-intuitive to focus on environmental costs over short-term benefits. But the long term view advocates otherwise with the sustainable exploitation of resources and actions taken to limit environmental damage, as it will eventually affect stakeholders.

Small electronics producers could take an active stance to prevent hoarding of small electronics by consumers. Increasing collection rates of small electronics would be beneficial to their business as they could exploit the growing feedstock of second-hand devices in working order to be reused (Deloitte, 2017); they will have a positive impact on society as they promote the principles of sustainable development and they will have a positive impact on the environment as fewer primary resources will be exploited. Moreover, millennials can be acutely aware of environmental issues (Williams et al., 2017) and are reported to be keen to favour sustainable consumption (Wilhem, 2012). Small electronics producers such as Apple, Samsung or Huawei could use the TBL to drive their strategy for the 21st century. They could recognise the endowment effect when designing methods and processes to prevent hoarding.

With the endowment effect influencing individuals' behaviour and associated with screen time (§5.4.2.1), owners estimate their end-of-use device at a higher value than the market (Table 5.6). Small electronics producers, such as Apple or Samsung, could inform owners that keeping the device in storage will not only reduce its monetary value and it might not be used for its intended purpose (Table 5.5b). Therefore, the end-of-use device could be considered as an opportunity to discount the acquisition price tag of new device. Some owners already do that as approximately 40% don't have a backup phone (Figure 5.1, Table 5.5), however some owners, especially those with high screen time, tend to have more hoarded devices (Figure 5.4). Small electronics producers adopting the TBL could reinforce the message that trading-in immediately a device is more beneficial to owners than storing it for a later potential and uncertain reuse or trading-in opportunity.

Figure 6.2 presents the Theory of Endowed Behaviour as a segment of a wider framework designed to enhance mobile and smart phones collection rates. It demonstrates hoarding decisions using screen time as a proxy to the endowment effect and the positive effect of the TBL on small electronics producers. The first stage is to prevent hoarding decisions by explaining to owners, when they acquire a new mobile device, that hoarding reduces the device's utility over time as well as its value and should rather be traded in immediately. The second stage is for small electronics producers to access hoarded devices and how owners could reduce the primary device acquisition cost by trading in their hoarded devices. The aim is to use existing collection and resales systems and simply to improve the link physical between households and these systems.

To counter the endowment effect and access hoarded devices, incentives associating market-based monetary incentives and user preferences, such as phone accessories, could be used. This would entice consumer to complete the "first-mile", which is usually a costly conundrum for any organisation trying to tangibly connect households and their business.

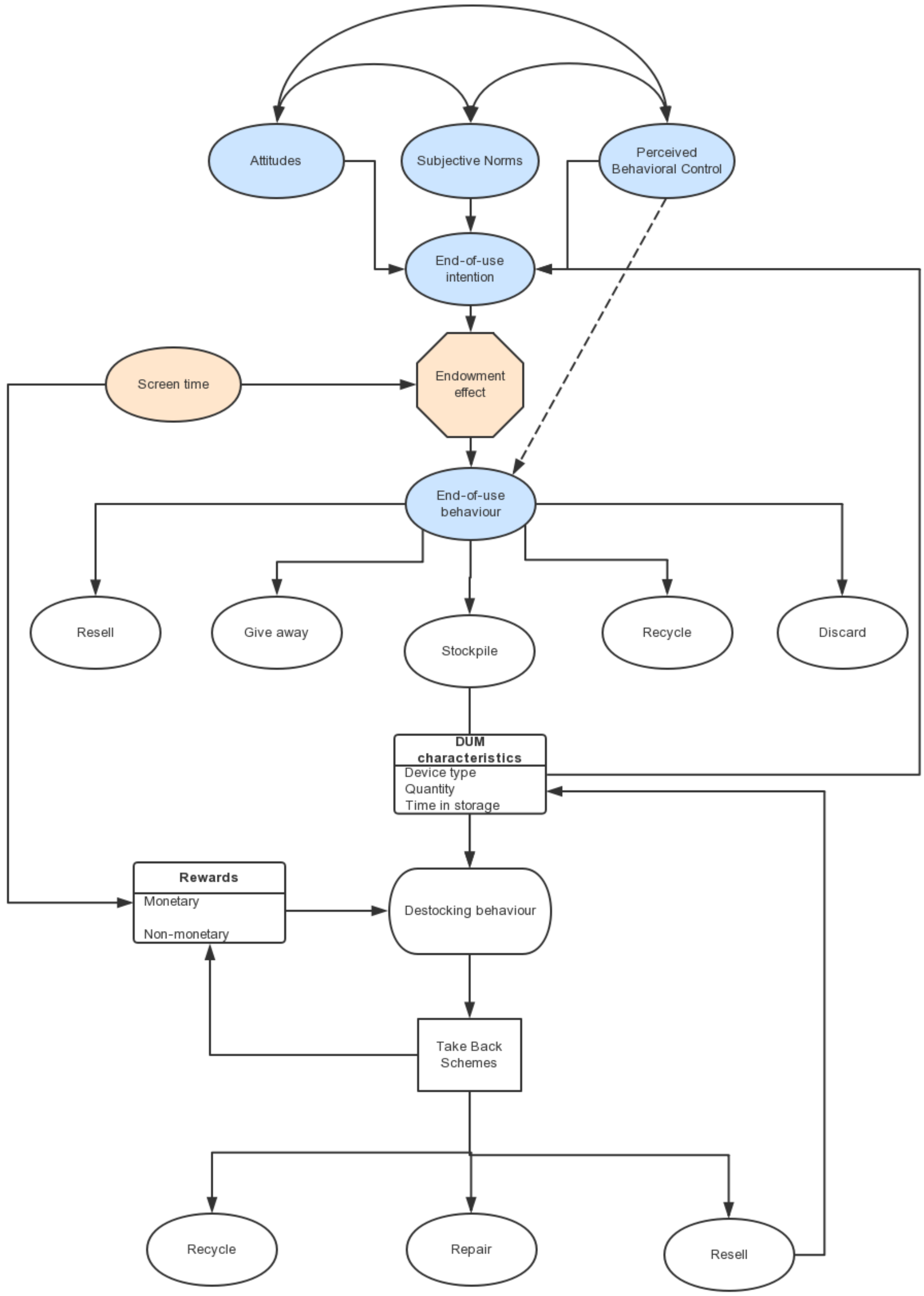



Figure 6.2: Theory of Endowed Behaviour to justify hoarding decisions and staged approach for small electronics producers to prevent hoarding and access existing DUM

### 6.2.2 Hoarded devices DUM exploitation with Choice Architecture / Stage 2

Contract renewal or new device acquisition could be used as a contact point to capture end-of-use devices before they are hoarded, but also to exploit small electronics DUM composed of hoarded devices (Figure 6.2).

When owners renew their contract, or acquire a new phone, small electronics producers could explain that hoarded devices could be sold back to them to lower the new device price tag (Figure 6.2). To counter the endowment effect on hoarded devices and to entice owners to extract the unused mobile device from storage, non-monetary incentives could be added to existing monetary rewards. Monetary rewards are necessary as they reflect the device second-hand market value but are insufficient due to the distortion brought by the endowment effect (Table 5.5). Young adults have expressed a view that they would be interested in getting phone accessories in return for giving back their unwanted phone (Table 5.13). This non-monetary incentive could be added to the device's second-hand value, in effect improving the leverage of the monetary incentive to discourage hoarding. To ensure owners would make the effort to come back to the small electronics producer, or mail the hoarded devices, the non-monetary incentives would be limited in time. If no time-limit is conditioned to the monetary incentive, the owner might lose the utility created for the non-monetary incentive and might not engage in the de-hoarding activity. For example, the non-monetary incentive would be offered during a seven-day period after the contact point. An Apple store sells an iPhone 6S smartphone case for £35 (Apple, 2018) but its production cost is much lower. In effect, the actual cost of "giving-away" a case is a non-monetary incentive that does not cost Apple more than a reduced or lost profit. To further explore how non-monetary and monetary incentives could be adapted, the principles and practices of Choice Architecture could be used (Thaler and Sustein, 2008).

Behavioural economics with Choice Architecture (Thaler et al., 2008; 2014) could be used to offer small electronics producers a methodology to design incentive mixes based on non-monetary and monetary rewards. Choice architecture is a behavioural economics principle considering users' biases to improve the decision-making process outcome (Figure 6.2, Table 6.1). This approach, sometimes called "libertarian paternalism" (Thaler, 2003), aims to structure the decision-making process against decision biases. In the mobile devices situation, the aim is to counter the owners' decision-making biases generated by the endowment effect. Choice architecture uses six underlying concepts illustrated by the NUDGES acronym (Thaler and Sustein, 2008): iNcentives, Defaults, Giving feedback, Expecting errors and Structuring complex choices (Table 6.1).

Table 6.1: Choice Architecture principles applied to nudging mobile and smart phone owners to trade-in their hoarded device (Thaler and Sunstein, 2008)

| NUDGES | Description |
|---|---|
| **iNcentives** | Incentive mix (monetary and non-monetary) based on hoarded device characteristics and owners' categorical variables (screen time, gender) |
| **Understanding mappings**[13] | Small electronics producers explain hoarded mobile devices' value declines over time to nudge decision to use hoarded devices as an additional discount toward the acquisition of a new device |
| **Defaults** | Default decision for mobile and smart phones tends to be hoarding. Small electronics producers to counter this default and nudge owners to trade-in their hoarded device within a time period |
| **Giving feedback** | Giving information to each owner: small electronics producers deliver information on hoarded device second-hand value, incentive mix based on device characteristics and owner's categorical variables, information on sustainable practice (what happens to the phone when collected by small electronics producers with positive impact on carbon footprint and reduced resources depletion) |
| **Expecting errors** | Incentive mix not adapted to owner preferences. Small electronics producers to use data gathered over time and experience to improve incentive mix |
| **Structuring complex choices** | Structure decision into logical steps:<br>Owner to understand that hoarding has marginal utility as usually devices are not used for their intended purpose<br>Hoarded devices' value declines over time so will the incentive mix. Immediate decision has the highest utility for owner<br>Owner is contributing to positive outcome for the environment and the circular economy |

The NUDGES concept (Thaler and Sustein, 2008; Table 6.1) addresses the endowment effect by offering an adapted incentive mix to each user, depending on the device and owner

[13] How information presentation influences decisions

characteristics (Table 4.7). Adapting the incentive mix is crucial to overcoming the endowment effect and enticing owners to access their hoarded devices. Each owner has a specific preference and sensitivity to a given incentive mix. A strong incentive mix does not necessarily mean the highest possible monetary incentive and the most expensive non-monetary incentive. Instead a strong incentive mix is rather the optimal combination of monetary rewards and non-monetary incentives offered by a small electronics producer to meet individual expectations such that the desired effect (de-hoarding) is achieved (Table 5.12). This could be a lower monetary reward for the hoarded device, but a more enticing gadget or accessory for the newly-acquired device.

Exploiting DUM, or sometimes called Urban Mining, is today at the forefront of preoccupations from government, organisations and individuals. There are strategic as well as environmental implications.

### 6.2.3 Chapter conclusion

To prevent mobile and smart phone DUM generation, an improved collection framework for small electronics based on the Theory of Endowed Behaviour and improved reward systems to lower the barriers set by the Endowment Effect has been proposed. To refine DUM exploitation approach, a distinction between exploitable stock and safety stock has been made. Then, Choice Architecture could be used to determine the optimum incentive mix between monetary and non-monetary rewards to exploit small electronics DUMs.

To exploit DUMs recommendations usually focus on improving monetary incentives (Welfens et al. (2014) or convenience (Ongondo and Williams (2011). Collection systems design could integrate Choice Architecture as an “adaptive toolbox” Gigerenzer (2002) to cater to different types of electronics when designing collection systems. Electronics come in all shapes and sizes but the Endowment Effect and the association of non-monetary incentives specifically designed for these types of electronic could help exploiting DUMs for different types of electronics over the long term.

Future research could determine the optimal balance between monetary and non-monetary rewards to exploit DUMs

# Chapter 7 Thesis Conclusion and Recommendations

Overarching aim: To explore and confirm new behavioural factors influencing the storage of small electronic devices, using mobile and smart phones among young adults as a case study.

This PhD research has achieved its four aims. The first aim was to evaluate and analyse critically current behavioural models associated with end-of-use decision-making. Chapter 2 reviewed behavioural models associated to waste and resource management. Given the restricted number of behavioural studies dedicated to e-waste and small e-waste, the decision was made to incorporate behavioural models associated to waste management in general. The TPB emerged as a widely-used model among scholars. The TPB and some derived models were analysed to identify which factors had the most influence on variance explained. It emerged that TPB-related models including emotions tended to be more successful for intentions, but not necessarily for behaviour.

The second research aim was to identify and evaluate critically factors associated to electronics end-of-use decision-making. Chapter 4 reported the results from a Delphi consultation among waste and resource management practitioners mostly from Western Europe. A list of factors from TPB studies and behavioural economics were submitted to the panel to select the most relevant for small e-waste end-of-use decision-making. They identified 14 factors associated to user preferences and device characteristics.

The third aim was to propose a theoretical model specific to small electronics end-of-use decision-making. Chapter 5 analysed the results from a social survey conducted among young adults from two UK universities. The amount of screen time reported had an influence on the subjective valuation students had for their mobile device. Respondents with higher screen time tended to have more devices hoarded. These findings were then incorporated into a new, original TPB-related model specific to mobile and smart phones, entitled the Theory of Endowed Behaviour.

The fourth research aim was to discuss critically the influence of behavioural factors on small electronics hoarding decisions. Chapter 6 proposed a framework based on the Theory of Endowed Behaviour and hoarding behaviour associated to the endowment effect. The endowment effect should be considered when designing collection systems to prevent hoarding.

## 7.1 Review of research objectives

**Objective 1: Analyse end-of-use behavioural models from the waste and resource management literature**

Studies developing end-of-use decision models usually focus on household recycling behaviour and there is a limited of corpus of studies exploring small electronics using a consistent set of factors. Therefore, the decision was made to investigate factors associated to TPB-related studies, a model widely used in waste and resource management.

**Objective 2: Appraise key factors involved in models' intention variance**

Models using the TPB and associating anticipated emotions have higher variance explained for intention but were less consistent for behaviour.

**Objective 3: Use expert knowledge to select factors associated with decision-making regarding small electronic devices**

A qualitative Delphi study in two rounds filtered down the number of variables of interest from 69 to 14. The organisation of a Delphi study allowed the collaboration of waste and resource management practitioners mainly across Western Europe.

**Objective 4: Critically analyse factors associated to small electronic devices**

The Delphi study results revealed that factors concomitant to user preference, such as utility for the device and device characteristics, such as its size, were more relevant to small electronics end-of-use decisions; than factors normally associated to waste management studies, such as environmental concerns or altruism. User preferences are: time-saving, utility for the device, limited experience or awareness, data confidentiality. Some factors pertain to both categories, such as quantity and time in storage, unbroken status and data storage capacity.

**Objective 5: Confirm prominent behavioural factors specific to mobile and smart phones**

The Endowment Effect has been consistently demonstrated among smart phone users. Respondents (young adults) from this study are not fully representative of the wider UK student population for gender and degree. Students reported higher subjective valuations as opposed to objective market-based value of their device. These higher valuations were defined as the endowment effect and associated to screen time. The longer people spent daily on the smart phone, the stronger the endowment effect. Students with higher screen time tend to have more expensive devices as well. Screen time is a strong proxy of the Endowment Effect.

**Objective 6: Measure the influence of behavioural factors on the storage in households of small electrical and electronic devices**

Screen time has been statistically correlated to more variables than other categorical variables such as utility, gender, degree type or fee status. Students reporting high screen time, not only have a stronger endowment effect, but they spend more on monthly basis to service their contract, they tend to have more data stored, take longer before re-selling their device and report a higher utility for their device. Perhaps as importantly, students with high screen time have more device stored away than students with medium or low values.

**Objective 7: Define new end-of use profiles based on small electronics behavioural factors**

A large number of students do not have any backup device, but a large majority have a backup and sometimes several. Students having a single backup device declared that it was important to have access readily to such a device as a backup. However, students who have several devices stored away do not have a specific purpose for these additional devices. From a waste and resource management perspective, backup phones that do not have a specific purpose should be considered as worth exploiting within a Distinct Urban Mine. Therefore, we propose a clear segmentation between stockpilers who have a single backup device that could be qualified as safety stock and hoarders, who have several devices stored away, which could be associated to exploitable stock. This segmentation is based on past behaviour rather than future hypothetical intentions, a limitation that has been identified in the literature review with previous waste and resource management models.

**Objective 8: Design a framework based on the Theory of Planned Behaviour to recognise and prevent small electronics hoarding**

Using the TPB associated with the endowment effect, screen time and profiles, a Theory of Endowed Behaviour was suggested. Based on this model specific to small electronics, this research proposed a framework acknowledging the influence of the endowment effect on hoarding decisions. Small electronics producers embracing the Triple Bottom Line concept could take an active role in informing owners when they replace their primary device of the “un-utility” hoarding devices represent. These producers could help owners being better informed about the fate on these unused devices and how they could contribute to a better environment, if reinserted into the economy by being traded-in.

**Objective 9: Propose a method using Choice Architecture to exploit small electrical and electronics Distinct Urban Mines**

At the same time, when owners decide to replace their primary device and if they have hoarded devices, small electronics producers could offer an incentive mix based on monetary and non-monetary rewards to overcome the endowment effect that has led to hoarding several devices. To help them designing optimum incentive mixes adapted to user preferences, Choice Architecture is recommended to structure the decision-making process toward exploiting Distinct Urban Mines composed of hoarded devices.

## 7.2 Implications

There are multiple implications for the waste and resource management sectors, local and national governments, policy-makers and small electronics producers.

For waste and resource management academics, the inclusion of behavioural economics principles when describing electronics end-of-use behaviour could bring additional insights and opportunities to counter subjective biases in the decision-making process. It could also enable the development of evidence-based new models and decision-making tools, for small or large electronics, as well as any household items that have been stockpiled or hoarded. The works of Kahneman, 2002 Economics Nobel Prize (Nobel Prize, 2018) have influenced the fields of psychology and economics (The Economist, 2011). Advances have been made into better understanding how human biases affect judgement and how these biases should be better understood to shape systems (Thaler and Sustein, 2008).

For policy-makers, and for example the Behavioural Insights Team (BIT), working in close cooperation with the British government, this implies that further work into the decision-making biases should be considered when producing legislation. The Behavioural Insights Team use data science to better understand social patterns to inform social policy (BIT, 2017). For the waste and resource management policy field, this implies taking into account the households and users' behaviour biases when designing systems aimed at improving collection rates to achieve a circular economy. With Brexit, the UK government could take back full ownership of its WEEE regulations and include CSR principles into its next WEEE recast. New WEEE legislation informed by behavioural economics could include CSR principles to entice EEE producers to become active members of the circular economy.

For small EEE producers and producers of larger EEE as well, there is a profit-based implication to gradually transition towards a circular economy. In developed economies, electrical and electronics market are saturated and the progression rates are low. It makes business-sense to encourage these producers to shift towards a service-based business model. They have an incentive to manufacture long lasting products and can benefit from recurring stable revenues derived from leasing these products to consumers (Ellen McArthur Foundation, 2018).

Consumers are more sensitive to environmental issues than ever before (Williams et al., 2017) and smart phone markets are stalling in developing economies (Deloitte, 2017). Small electronics producers need to find value growth relays. To adapt to this evolving business context, leading small electronics producers, such as Apple or Samsung, could take an active role. They could go beyond the obligations placed by the WEEE directive (Directive 2012/19/EU) and lead the way towards a circular economy; by switching towards a service-based business, rather than manufacturing-based. Several businesses associated to the Ellen McArthur foundation have taken active steps to accelerate the transition towards a circular economy. A prominent example is from Royal Philips in the Netherlands. They have developed a “Pay-per-lux” business model where lighting is purchased as a service and the company is responsible for maintenance, reconditioning and recovery (Ellen McArthur Foundation, 2018).

## 7.3 Applications

Hoarding prevention and exploitation could be applied to other small electronics and additional population segments. In other words, any electronics that is small enough to be conveniently stored away; for example, tablets and laptops or all small home entertainment products including games, toys and viewing platforms (Ongondo et al., 2013). Perhaps even desktops or TVs, if households have enough storage space, as suggested by Saphores et al. (2009). The stockpiling and hoarding definitions, as well as the application of the endowment effect, is wider than home electronics. Conceivably, anything that is hoarded by households.

Efforts to prevent hoarding and exploit hoarded household goods could be promoted and sustained by the very organisations placing these items on the market.  In a service-based economy, these devices could be refurbished when required against monthly payments. To achieve a circular economy producers representing products entry point on the market could be these products reinsertion points into the circular economy. The key is to change the idea of ownership. Instead of owning products, individuals could lease them from companies and these organisations would ensure these products are maintained and replaced when necessary to secure their service-based revenue stream.

Future research could use other Behavioural Economics concepts, such as Status Quo Bias or Loss Aversion, to further investigate end-of-use barriers for small electronics, as well as for other hoarded items within households. Better understanding hoarding decisions will help designing systems to address these barriers, prevent DUM generation, increase collection rates and further close the loop for a Circular Economy.

## 7.4 Limitations and future research

This study has some limitations and future research avenues could be considered.

There are a limited number of studies dealing with e-waste, let alone small e-waste, end-of-use behaviour. Therefore, studies dealing with household waste end-of-use behaviour were selected to extract behavioural factors. End-of-use behaviour factors differ according to the type of waste, its size, if it can be stored easily or not. Further research dealing specifically with e-waste and small e-waste end-of-use behaviour could favour the emergence of behavioural factors specific with this type of “waste”.

The Theory of Planned Behaviour is criticised for being more successful on explaining variability for intentions than actual behaviour. Further research could focus on factors directly affecting behaviour rather than intentions.

The Delphi panel was composed of professionals and academics dealing with waste management in general and mostly from the UK, Germany and Belgium. Their perceptions towards small e-waste end-of-use behaviour might be different than from professionals dealing with small e-waste. Future research could focus more specifically on these professionals and compare views with waste management professionals and academics. It could also be argued that the professional opinions from waste management professionals and academics might different from the concerns young adults studying in the UK might have for their mobile phones at their end-of-use.

The methodology to administrate the Delphi study, PAPRIKA (Hansen and Ombler, 2008), is less known than AHP from Saaty (1980) but is more convenient for respondents. Future research could associate DELPHI and AHP and compare results obtained with PAPRIKA.

The social survey sample was not fully representative of the wider UK student population at the time of study. Further research could seek to gather data on a wider sample base across the UK and perhaps to other population segments than just students. The results from the categories that have not demonstrated a correlation between screen time and the endowment effect, namely overseas' students, PG students and Coventry Business School students, might benefit from a wider sample base to demonstrate correlation.

Using Likert scales to evaluate screen time was more convenient for respondents but the results are less precise if obtained with continuous data. Further research could be made on the amount of time is spent using a mobile device, or how many times the device is being picked up every day. Some operating systems now report this information, although only on the latest updates.

The word cloud approach to define incentives and reasons for stockpiling or hoarding is fuzzy as the comments left by respondents are open. A more structured approach and proposing categories could improve interpretation and accuracy. Further research could be made on the type of devices that are being hoarded, their brand, their working status, etc. This could help better quantifying the value and volume of this existing DUM to measure efforts to exploit it.

The correlation highlighted between screen time and the quantity of hoarded devices is by no means causation. Further research exploring the connection between screen time and end-of-use behaviours might be warranted.

The Theory of Endowed Behaviour has been proposed based upon the reported association of behaviour to screen time and validated by  the correlations demonstrated by some elements of the sample. These correlations could be further tested and investigated on a larger sample size, using different population segments and other small electronics with a screen such as tablets, laptops,  smartwatches,  PCs or televisions.

Modern smart phones now report screen time and other variables such as pick up times on daily, weekly and monthly basis. These data are now readily available. Hence data to estimate screen time could be collected more efficiently and potentially fed into apps or software to further explore correlations with other variables. The number of pick-up times might be more useful than actual screen time for some population segments. For example, working adults might not spend a significant amount of time daily using their phone, but might pick-up the device a high number of times. Pick-up times and their association to the endowment effect could be further investigated.

As modern smart phones have access to large amount of data based on the cloud, a phone's current monetary value could be displayed to owners on a weekly basis for example. The aim would be to explore if the endowment effect could be reduced if owners had access to real-time information. A reduction of the endowment effect could reduce hoarding decisions and increase the number of devices back into the circular economy.

# List of References

Apple (UK), (2016). *'iPhone 6/ 6s Silicone Case - Midnight Blue'*. [online] Available at: https://www.apple.com/uk/shop/product/MKY22ZM/A/iphone-6-6s-silicone-case-midnight-blue?afid=p238%7CsL4w7cF5j-dc_mtid_187079nc38483_pcrid_104154899041_&cid=aos-uk-kwgo-pla-btb--slid-----product-MKY22ZM/A-UK [Accessed 22 Aug. 2018].

About.sainsburys.co.uk, (2018). *'Environment'*. [online] Available at: https://www.about.sainsburys.co.uk/making-a-difference/environment [Accessed 28 Aug. 2018].

Afroz, R., Masud, M. M., Akhtar, R. and Duasa, J. B. (2013). Survey and Analysis of Public Knowledge, Awareness and Willingness to Pay in Kuala Lumpur, Malaysia - a Case Study on Household WEEE Management. *Journal of Cleaner Production*, 52, pp. 185-93.

Ajzen, I. (1985). From Intentions to Actions: A Theory of Planned Behavior. *Springer Berlin Heidelberg: In Action Control*, edited by PD Dr Julius Kuhl and Dr Jürgen Beckmann, pp.11-39.

Ajzen, I., 1991. The theory of planned behavior. Organizational Behavior and Human Decision Processes, *Theories of Cognitive Self-Regulation* 50, 179–211.

Ajzen, I. (2011). The Theory of Planned Behavior: Reactions and Reflections. *Psychology & health*, 26, pp. 1113-27.

Amazon.co.uk, (2018). [online] Available at: https://www.amazon.co.uk/ [Accessed 11 Sep. 2018].

Alamgir, M., Bidlingmaier, W., Cossu, R., Wang, F., Huisman, J., Meskers, C. E. M., Schluep, M., Stevels, A. and Hagelüken, C. (2012). The Best-of-2-Worlds Philosophy: Developing Local Dismantling and Global Infrastructure Network for Sustainable E-Waste Treatment in Emerging Economies. *Waste Management*, 32 (1), pp. 2134-46.

Archibald, M. M., Radil, A. I., Zhang, X. and Hanson, W. E. (2015). Current Mixed Methods Practices in Qualitative Research: A Content Analysis of Leading Journals. *International Journal of Qualitative Methods*, 14 (2), pp. 5-33.

Armitage, C. J. and Conner, M. (2001). Efficacy of the Theory of Planned Behaviour: A Meta-Analytic Review. *The British Journal of Social Psychology / the British Psychological Society*, Pt 4 (40), pp. 471-99.

Arora, R., Paterok, K., Banerjee, A. and Saluja, M.S. (2017). Potential and relevance of urban mining in the context of sustainable cities. *IIMB Management Review,* 29, pp. 210-224.

Balleine, B. W, Dezfouli, A., Ito, M, and Doya, K. (2015). Hierarchical Control of Goal-Directed Action in the Cortical - basal Ganglia Network. *Current Opinion in Behavioral Sciences, Neuroeconomics*, 5, pp. 1-7.

Bamberg, S., Hunecke, M. and Blöbaum, A. (2007). Social Context*,* Personal Norms and the Use of Public Transportation: Two Field Studies. *Journal of Environmental Psychology,* 27 (3), pp. 190-203.

Barata, R. and Castro, P. (2013). "I Feel Recycling Matters… Sometimes": The Negative Influence of Ambivalence on Waste Separation among Teenagers. *The Social Science Journal*, 50(3), pp. 313-20.

Barba-Gutiérrez, Y., Adenso-Díaz, B. and Hopp, M. (2008). An Analysis of Some Environmental Consequences of European Electrical and Electronic Waste Regulation. *Resources, Conservation and Recycling,* 52 (3), pp. 481-95.

Barr, S. (2007). Factors Influencing Environmental Attitudes and Behaviors A U.K. Case Study of Household Waste Management. *Environment and Behavior*, 39 (4), pp. 435-73.

Barr, S. and Gilg, A. W. (2005). Conceptualising and Analysing Household Attitudes and Actions to a Growing Environmental Problem: Development and Application of a Framework to Guide Local Waste Policy. *Applied Geography*, 25(3), pp. 226-47.

Barr, S., Gilg, A. W. and Ford, N. J. (2001). A Conceptual Framework for Understanding and Analysing Attitudes towards Household-Waste Management. *Environment and Planning A*, 33(11), pp. 2025-48.

Barr, S., Guilbert, S., Metcalfe, A., Riley, M., Robinson, G.M. and Tudor, T. L. (2013). Beyond recycling: An integrated approach for understanding municipal waste management. *Applied Geography,* 39, p. 67-77.

Baxter, J. and Gram-Hanssen, I. (2016). Environmental message framing: Enhancing consumer recycling of mobile phones. *Resources, Conservation and Recycling*, 109 (02), pp. 96-101.

Behaviouralinsights.co.uk, (2018). *The Behavioural Insights Team*. [online] Available at: https://www.behaviouralinsights.co.uk/ [Accessed 22 Aug. 2018].

Biber, H., Nagy, S. and Johnson, R. B. (2015). *The Oxford Handbook of Multimethod and Mixed Methods Research Inquiry*. Oxford University Press.

Binnemans, K., Jones, P. T., Blanpain, B., Van Gerven, T., Yang, Y., Walton, A. and Buchert, M. (2013). Recycling of rare earths: a critical review*, Journal of Cleaner Production,* 51, pp. 1-22.

Black, T. R. (1999). Doing Quantitative Research in the Social Sciences: An Integrated Approach to Research Design, Measurement and Statistics. London: SAGE Publications Ltd, 1 edition.

Blake, J. (1999). Overcoming the 'value-action gap' in environmental policy: Tensions between national policy and local experience. *Local Environment* 4, 257–278.

Bloomberg.com, (2010). *China Denies Japan Rare-Earth Ban Amid Diplomatic Row*. [online] Available at: http://www.bloomberg.com/news/articles/2010-09-23/china-denies-japan-rare-earth-ban-amid-diplomatic-row-update1- [Accessed 23 Sep. 2010].

Bloor, M., Sampson, H., Baker, S. and Dahlgren, K. (2015). Useful but No Oracle: Reflections on the Use of a Delphi Group in a Multi-Methods Policy Research Study*. Qualitative Research*, 15 (1), pp. 57-70.

Bor, Y.J., Chien, Y. -L. and Hsu, E. (2004). The market-incentive recycling system for waste packaging containers in Taiwan. *Environmental Science & Policy*, 7, pp. 509-523.

Bortoleto, A. P., Kurisu, K. H. and Hanaki, K. (2012). Model Development for Household Waste Prevention Behaviour. *Waste Management*, 32 (12), pp. 2195-2207.

Bouton, M. E. (2014). Why Behavior Change Is Difficult to Sustain*. Preventive Medicine, Behavior Change, Health, and Health Disparities*, 68, pp. 29-36.

Bouzon, M., Govindan, K., Rodriguez, C. M. T. and Campos, L. M. S. (2016). Identification and Analysis of Reverse Logistics Barriers Using Fuzzy Delphi Method and AHP. *Resources, Conservation and Recycling*, 108, pp. 182-97.

Bigum, M., Petersen, C., Christensen, T.H. and Scheutz, C. (2013). WEEE and portable batteries in residual household waste: Quantification and characterisation of misplaced waste. *Waste* Management, 33, pp. 2372-2380.

Bradsher, K. (2014). *Rare Earth Prices Soar as Efforts to Increase Supplies Falter*. [online] Nytimes.com. Available at: https://www.nytimes.com/2011/05/03/business/03rare.html [Accessed 7 Feb. 2019].

Brown, Z. S. and Johnstone, N. (2014). Better the Devil You Throw: Experience and Support for Pay-as-You-Throw Waste Charges. *Environmental Science & Policy,* 38, pp. 132-42.

Byrne, S. and O'Regan, B. (2014). Attitudes and Actions towards Recycling Behaviours in the Limerick, Ireland Region. *Resources, Conservation and Recycling*, 87, pp. 89-96.

Cahill, R., Grimes, S. M. and Wilson, D. C. (2011). Extended Producer Responsibility for Packaging Wastes and WEEE - a Comparison of Implementation and the Role of Local Authorities across Europe. *Waste Management & Research : The Journal of the International Solid Wastes and Public Cleansing Association*, 29 (5), pp. 455-79.

Cain, J. and Malcom, D.R. (2018). An Assessment of Students' Psychological Attachment to Smartphones at Two Colleges of Pharmacy American, *Journal of Pharmaceutical Education e-View*, 7136.

Caniato, M., Vaccari, M., Visvanathan, C. and Zurbrügg, C. (2014). Using Social Network and Stakeholder Analysis to Help Evaluate Infectious Waste Management: A Step towards a Holistic Assessment. *Waste Management,* 34(5), pp. 938-51.

Carrus, G., Passafaro, P. and Bonnes, M. (2008). Emotions, Habits and Rational Choices in Ecological Behaviours: The Case of Recycling and Use of Public Transportation. *Journal of Environmental Psychology,* 28(1), pp. 51-62.

Chan, K. (1998). Mass communication and pro-environmental behaviour: waste recycling in Hong Kong. *Journal of Environmental Management*, 52, pp. 317-325.

Chan, L. and Bishop, B. (2013). A moral basis for recycling: Extending the theory of planned behaviour. *Journal of Environmental Psychology*, 36, pp. 96-102.

Collins, K.M.T., Onwuegbuzie, A.J., Jiao, Q.G. (2007). A Mixed Methods Investigation of Mixed Methods Sampling Designs in Social and Health Science Research. *Journal of Mixed Methods Research* 1, 267–294.

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. Closing the loop - An EU action plan for the Circular Economy. COM/2015/0614 final

Compareandrecycle.co.uk, (2018). *Compare Apple Recycle - Recycler Details - Compare and Recycle*. [online] Available at: https://www.compareandrecycle.co.uk/apple-recycle [Accessed 28 Aug. 2018].

Corral-Verdugo, V., (1997). Dual 'Realities' of Conservartion Behavior: Self-Reports vs Obervations of Reuse and Recyling Behavior. *Journal of Environmental Psychology* 17, 135–145.

Cossu, R. and Williams, I. D. (2015). Urban Mining: Concepts, Terminology, Challenges. *Waste Management, Urban Mining*, 45, pp. 1-3.

Creswell, J. W. and Clark, P. (2007). Health Promotion – Principles and Practice in the Australian Context. *Australian and New Zealand Journal of Public Health,* 31(4), pp. 388-89.

Cruz-Sotelo, S., Ojeda-Benítez, S., Jáuregui Sesma, J., Velázquez-Victorica, K., Santillán-Soto, N., García-Cueto, O., Alcántara Concepción, V., Alcántara, C., Cruz-Sotelo, S.E., Ojeda-Benítez, S., Jáuregui Sesma, J., Velázquez-Victorica, K.I., Santillán-Soto, N., García-Cueto, O.R., Alcántara Concepción, V., Alcántara, C. (2017). E-Waste Supply Chain in Mexico: Challenges and Opportunities for Sustainable Management. *Sustainability* 9, 503.

Curzon, H. F. and Kontoleon, A. (2016). From Ignorance to Evidence? The Use of Programme Evaluation in Conservation: Evidence from a Delphi Survey of Conservation Experts. *Journal of Environmental Management,* 180, pp. 466-75.

Dalkey, N. and Helmer, O. (1963). *An Experimental Application of the DELPHI Method to the Use of Experts*. *Management Science,* 9, p. 458-467.

Darby, L. and Obara, L. (2005). Household recycling behaviour and attitudes towards the disposal of small electrical and electronic equipment. *Resources, Conservation and Recycling,* 44, pp. 17-35.

Darnton, A. (2008). Reference Report: An Overview of Behaviour Change Models and Their Uses. *GSR Behaviour Change Review*, 83.

Daum, K., Stoler, J., Grant, R., Daum, K., Stoler, J. and Grant, R. J. (2017). Toward a More Sustainable Trajectory for E-Waste Policy: A Review of a Decade of E-Waste Research in Accra, Ghana. *International Journal of Environmental Research and Public Health,* 14(135).

Davies, J., Foxall, G. and Pallister, J. (2002). Beyond the Intention-Behaviour Mythology An Integrated Model of Recycling. *Marketing Theory*, 2(1), pp. 29-113.

Davies, J., Foxall, G. R. and Pallister, J. (2002). Beyond the Intention-Behaviour Mythology An Integrated Model of Recycling. *Marketing Theory,* 2(1), pp. 29-113.

De Leeuw, A., Valois, P., Ajzen, I. and Schmidt, P. (2015). Using the Theory of Planned Behavior to Identify Key Beliefs Underlying pro-Environmental Behavior in High-School Students: Implications for Educational Interventions*. Journal of Environmental Psychology,* 42, pp. 128-38.

De Vaus, D. A. (2002). *Surveys in Social Research*. [online] London: Routledge, 5th Ed. [Accessed 31 Mar. 2018].

Delbari, S. A., Ng, S. I., Aziz, Y. A. and Ho, J. A. (2016). An Investigation of Key Competitiveness Indicators and Drivers of Full-Service Airlines Using Delphi and AHP Techniques. *Journal of Air Transport Management,* 52, pp. 23-34.

Deloitte (2016). *Predictions 2016: Trailing Millennials Are the pro-PC, Not the Post-PC, Generation | Technology, Media, and Telecommunications*. [online] Deloitte Israel. Available at: http://www2.deloitte.com/il/en/pages/technology-media-and-telecommunications/articles/tmt-pred16-tech-millennials-pro-pc-not-post-pc.html. [Accessed 31 Mar. 2018].

Deloitte (2018). *Predictions 2016: Used smartphones: $17 billion market you never heard of | Technology, Media, and Telecommunications*. [online] Available at: https://www2.deloitte.com/global/en/pages/technology-media-and-telecommunications/articles/tmt-pred16-telecomm-used-smartphones-17-billion-market.html [Accessed 21 Aug. 2018].

Department for Business Enterprise and Regulatory Reform (2008). *Annual Report and Accounts 2007-08*. [online] London: Department for Business, Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/248535/0757.pdf. [Accessed 31 Mar. 2018]

Department for Business Innovation and Skills (2013). Implementation of the WEEE Recast Directive 2012/19/EU and Changes to the UK WEEE System. [online] London: Department for Business Innovation and Skills, Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/249408/bis-13-1179-government-response-waste-electrical-and-electronic-equipment-weee-implementing-the-recast-directive-and-uk-system-changes.pdf [Accessed 31 Mar. 2018]

Department for Business Innovation and Skills (2009). The Waste Electrical and Electronic Equipment (Amendment) Regulations 2009. [online] London: Department for Business Innovation and Skills, Available at: https://data.gov.uk/data/.../09d4d821-76ff-4ba2-ab13-afb11fc453a1 [Accessed 31 Mar. 2018].

Di Maria, F., Micale, C., Sordi, S., Cirulli, G. and Marionni, M. (2013), Urban Mining: Quality and Quantity of Recyclable and Recoverable Material Mechanically and Physically Extractable from Residual Waste. *Waste Management*, 33 (12), pp. 2594-99.

Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste (Text with EEA relevance), 2018. 150.

Dirk, N., Saskia, M., Peeters, J. R., Paul, V., Nele, D. and Karl, V. (2013). A Multidimensional Indicator Set to Assess the Benefits of WEEE Material Recycling. *Journal of Cleaner Production*.

Dommer, S. L. and Swaminathan, V. (2013). Explaining the Endowment Effect through Ownership: The Role of Identity, Gender, and Self-Threat. *Journal of Consumer Research,* 39, pp. 1034-1050.

Donohoe, H., Stellefson, M. and Tennant, B. (2012). Advantages and Limitations of the E-Delphi Technique. *American Journal of Health Education*, 43(1), pp. 38-46.

Dwivedy, M. and Mittal, R. K. (2013). Willingness of Residents to Participate in E-Waste Recycling in India*. Environmental Development,* 6, pp. 48-68.

eBay, (2018). *Electronics, Cars, Fashion, Collectibles, Coupons and More | eBay.* [online] Available at: https://www.ebay.co.uk/ [Accessed 11 Sep. 2018].

Echagaray, F. and Hansstein, F. V. (2017). Assessing the intention-behavior gap in electronic waste recycling: the case of Brazil. *Journal of Cleaner Production*, 142, pp. 180-190.

Electronics Takeback Coalition, (2014). *'Facts and Figures on E-Waste and Recycling'*. [online] Available at: http://www.electronicstakeback.com/wp-content/uploads/Facts_and_Figures_on_EWaste_and_Recycling.pdf [Accessed 31 Mar. 2018].

Eliana, M.-R., Jambeck, J. R., Reeves, P. and Johnsen, K. (2016). Will They Recycle? Design and Implementation of Eco-Feedback Technology to Promote on-the-Go Recycling in a University Environment. *Resources, Conservation and Recycling,* 114, pp. 72-79.

Eliseeva, S.V. and Bünzli, J.-C.G. (2011). Rare earths: jewels for functional materials of the future. *New Journal of Chemistry,* 35 (1165).

Elkington, J. (1998). *Cannibals with forks*. Gabriola Island, BC: New Society Publishers.

Ellenmacarthurfoundation.org, (2012). *Selling light as a service.* [online] Available at: https://www.ellenmacarthurfoundation.org/case-studies/selling-light-as-a-service [Accessed 22 Aug. 2018].

Ellenmacarthurfoundation.org, (2018). *In depth - Mobile Phones - A Circular Economy Study*. [online] Available at: https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram/in-depth-mobile-phones [Accessed 5 Sep. 2018].

Emerson, R.W. (2015). Convenience Sampling, Random Sampling, and Snowball Sampling: How Does Sampling Affect the Validity of Research? *Journal of Visual Impairment & Blindness (Online*); Huntington 109, 164.

Envirofone.com, (2018). *Terms and Conditions | Mobile Phone Recycling | Envirofone*. [online] Available at: https://www.envirofone.com/en-gb/terms-and-conditions [Accessed 28 Aug. 2018].

European Commission, (2015). *Closing the Loop - An EU Action Plan for the Circular Economy.* [online] Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015DC0614. [Accessed at 31 Mar. 2018].

Ec.europa.eu, (2016). European Commission COM 739. [online] Available at: http://ec.europa.eu/environment/circular-economy/implementation_report.pdf [Accessed 6 Sep. 2018].

European Commission (2004). *Commission Directive 2004/79/EC of 4 March 2004 Adapting Directive 2002/94/EC, in the Field of Taxation, by Reason of the Accession of the Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia and Slovakia*. [online] Brussels: European Commission, Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32004L0079 [Accessed at: 31 Mar. 2018].

European Commission (2009). *Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.* [online] Brussels: European Commission, Available at [https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1550223698560&uri=CELEX:32009L0125](https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1550223698560&uri=CELEX:32009L0125) [Accessed at: 15 Feb. 2019]

European Commission (2010). *Critical Raw Materials for the EU. Report of the Ad-Hoc Working Group on Defining Critical Raw Materials.* [online] Brussels: European Commission, Available at: http://www.euromines.org/files/what-we-do/sustainable-development-issues/2010-report-critical-raw-materials-eu.pdf [Accessed at 31 Mar. 2018].

European Commission. (2002). *Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on Waste Electrical and Electronic Equipment (WEEE) - Joint Declaration of the European Parliament, the Council and the Commission Relating to Article 9*. [online] Brussels: European Commission, Available at: http://eur-lex.europa.eu/eli/dir/2002/96/oj [Accessed 31 Mar. 2018].

European Commission (2012). *Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on Waste Electrical and Electronic Equipment (WEEE) Text with EEA Relevance*. [online] Brussels: European Commission, Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32012L0019 [Accessed at 31 Mar. 2018]

European Commission - European Commission, (2018). *Data protection*. [online] Available at: https://ec.europa.eu/info/law/law-topic/data-protection_en [Accessed 28 Aug. 2018].

European Commission (2014). *Report on Critical Raw Materials for the EU. Report of the Ad Hoc Working Group on Defining Critical Raw Materials*. [online] Brussels: European Commission, Available at: https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en. [Accessed 31 Mar. 2018]

Eurostat, (2016). *Tertiary Education Statistics - Statistics Explained*. [online] Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Tertiary_education_statistics. [Accessed 31 Mar. 2018].

Eurostat, (2016). *Waste Electrical and Electronic Equipment (WEEE) - Eurostat*. [online] Available at: http://ec.europa.eu/eurostat/web/waste/key-waste-streams/weee. [Accessed 31 Mar. 2018].

Eurostat.ec.europa.eu, (2018). [online] Available at: http://appsso.eurostat.ec.europa.eu/nui/show.do?query=BOOKMARK_DS-185466_QID_-7E908AF_UID_-3F171EB0&layout=TIME,C,X,0;WASTE,L,Y,0;GEO,L,Z,0;WST_OPER,L,Z,1;UNIT,L,Z,2;INDICATORS,C,Z,3;&zSelection=DS-185466WST_OPER,COL;DS-185466GEO,AT;DS-185466UNIT,T;DS-185466INDICATORS,OBS_FLAG;&rankName1=WST-OPER_1_2_-1_2&rankName2=INDICATORS_1_2_-1_2&rankName3=UNIT_1_2_-1_2&rankName4=GEO_1_0_0_1&rankName5=TIME_1_0_0_0&rankName6=WASTE_1_0_0_1&sortR=ASC_-1_FIRST&sortC=ASC_-1_FIRST&rStp=&cStp=&rDCh=&cDCh=&rDM=true&cDM=true&footnes=false&empty=false&wai=false&time_mode=ROLLING&time_most_recent=false&lang=EN&cfo=%23%23%23.%23%23%23%2C%23%23%23 [Accessed 5 Sep. 2018].

Field, A. (2005). *Discovering Statistics Using SPSS. Third Edition edition*. Los Angeles: SAGE Publications Ltd.

Fishbein, M. and Ajzen, I. (1975). *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research*. Addison-Wesley Pub. Co.

Fletcher, A. J. and Marchildon, G. P. (2014). Using the Delphi Method for Qualitative, Participatory Action Research in Health Leadership. *International Journal of Qualitative Methods,* 13, pp. 1-18.

Gartner, (2016). *Worldwide Device Shipments to Grow 1.9 Percent in 2016, While End-User Spending to Decline for the First Time*. [online] Available at: http://www.gartner.com/newsroom/id/3187134 [Accessed 31 Mar. 2018]

Gartner.com, (2018). *Gartner Says Worldwide Sales of Mobile Phones Declined 2 Percent in First Quarter of 2012; Previous Year-over-Year Decline Occurred in Second Quarter of 2009*. [online] Available at: https://www.gartner.com/newsroom/id/2017015 [Accessed 11 Sep. 2018].

Gartner.com, (2018). *Gartner Says Worldwide Device Shipments Will Increase 2.1 Percent in 2018*. [online] Available at: https://www.gartner.com/en/newsroom/press-releases/2018-01-29-gartner-says-worldwide-device-shipments-will-increase-2-point-1-percent-in-2018 [Accessed 21 Aug. 2018].

Geyer, R. and Blass, V.D. (2009). The Economics of Cell Phone Reuse and Recycling. *The International Journal of Advanced Manufacturing Technology*, 47 (5-8), pp. 515-25.

Global E-waste Monitor 2017: amount of e-waste rising, only 20% is recycled - Institute for Environment and Human Security [WWW Document], n.d. URL https://ehs.unu.edu/news/announcement/e-waste-monitor-2017.html (accessed 10.11.18).

Ghani, K., Wan Ab, W. A., Rusli, I. F., Biak, D. R. A. and Idris, A. (2013). An Application of the Theory of Planned Behaviour to Study the Influencing Factors of Participation in Source Separation of Food Waste. *Waste Management*, 33(5), pp. 1276-81.

Ghisellini, P., Cialani, C. and Ulgiati, S. (2016). A Review on Circular Economy: The Expected Transition to a Balanced Interplay of Environmental and Economic Systems. *Journal of Cleaner Production, Towards Post Fossil Carbon Societies: Regenerative and Preventative Eco-Industrial Development*, 114, pp.11-32.

Gideon, D. L. (2012). *Handbook of Survey Methodology for the Social Sciences*. New York: Not Avail.

Gigerenzer, G. (2002). *Bounded Rationality: The Adaptive Toolbox*. Cambridge, Mass: New Ed edition. ed. MIT Press.

Gijsbers, H. J. H., Lauret, G. J., van Hofwegen, A. , van Dockum, T. A., Teijink, J. A. W. and Hendriks, H. J. M. (2016). *Development of Quality Indicators for Physiotherapy for Patients with PAOD in the Netherlands: A Delphi Study*. Physiotherapy 102(2), pp. 196-201.

Gill, F. J., Leslie, G. D., Grech, C. and Latour, J. M. (2013). Using a Web-Based Survey Tool to Undertake a Delphi Study: Application for Nurse Education Research. *Nurse Education Today,* 33(11), pp. 1322-28.

Green Alliance, (2015). *A Circular Economy for Smart Devices / Opportunities in the US, UK and India*. [online] Available at: http://www.green-alliance.org.uk/resources/A%20circular%20economy%20for%20smart%20devices.pdf. [Accessed at 31 Mar. 2018].

Greenpeace International, (2009). 'Where *Does E-Waste End up? | Greenpeace International'*. [online] Available at: http://www.greenpeace.org/international/en/campaigns/detox/electronics/the-e-waste-problem/where-does-e-waste-end-up/.

Grunow, M. and Gobbi, C. (2009). Designing the Reverse Network for WEEE in Denmark. *CIRP Annals - Manufacturing Technology,* 58(1), pp. 391-94.

Gurauskienė, Inga. (2008). The Behaviour of Consumers as One of the Most Important Factors in E-waste Problem. *Environmental Research, Engineering and Management*, 4, pp. 56-65.

GSM Arena, (2016). *GSMArena.com - GSM Phone Reviews, News, Opinions, Votes, Manuals and More...* [online] Availabile at: http://www.gsmarena.com/. [Accessed at 31 Mar. 2018].

Gumtree.com, (2018). *Gumtree | Free classified ads from the #1 classifieds site in the UK.* [online] Available at: https://www.gumtree.com/ [Accessed 11 Sep. 2018].

Gutberlet, J. (2015). Cooperative Urban Mining in Brazil: Collective Practices in Selective Household Waste Collection and Recycling. *Waste Management, Urban Mining*, 45, pp. 22-31.

Gutiérrez, E., Díaz, B. A., Lozano, S. and Torre, P. G. (2010). A Competing Risks Approach for Time Estimation of Household WEEE Disposal. *Waste Management (New York, N.Y.),* 30(8-9), pp. 1643-52.

Hansen, P. and Ombler, F. (2008). A New Method for Scoring Additive Multi-Attribute Value Models Using Pairwise Rankings of Alternatives. *Journal of Multi-Criteria Decision Analysis,* 15(3-4), pp. 87-107.

Hardesty, D. M. and Bearden, W. O. (2004). The use of expert judges in scale development. Implications for improving face validity of measures of unobservable constructs. *Journal of Business Research*, 57, pp. 98-107.

Hedt, B.L., Pagano, M. (2011). Health indicators: Eliminating bias from convenience sampling estimators. *Statistics in Medicine* 30, 560–568.

Herat, S. and Agamuthu, P. (2012). E-waste: a problem or an opportunity? Review of issues, challenges and solutions in Asian countries. *Waste Management Resources,* 30, pp. 1113-1129.

Hino, H., 2015. TV Today, Mobile TV Tomorrow? Extrapolating Lessons from Israeli Consumers' Adoption of Innovative TV Viewing Technology. *International Journal on Media Management* 17, 69–92.

Hopper, J. R. and Nielsen, J. M. (1991). Recycling as Altruistic Behavior Normative and Behavioral Strategies to Expand Participation in a Community Recycling Program. *Environment and Behavior,* 23(2), pp. 195-220.

Howell, D. C. (2010). *Cengage Advantage Books: Fundamental Statistics for the Behavioral Sciences. 7th Revised edition edition*. Belmont, CA: Broadman & Holman Publishers.

Hsu, C.-C. and Sandford, B. (2007). The Delphi Technique: Making Sense Of Consensus. *Practical Assessment, Research & Evaluation*, 12(10), pp. 8.

Huffman, A. H., Brittney, R. V. D. W., Henning, J. B. and Rodriguez, K. W. (2014). When Do Recycling Attitudes Predict Recycling? An Investigation of Self-Reported versus Observed Behavior. *Journal of Environmental Psychology*, 38, pp. 262-70.

Huisman, J. (2012*). Eco-efficiency evaluation of WEEE take-back systems. Waste Electrical and Electronic Equipment (WEEE) Handbook*. pp. 93-119.

Huisman, J. (2013). *WEEE Recast : From 4kg to 65 %: The Compliance Consequences*. United Nations University.

Huisman, J., Stevels, A., Marinelli, T, and Magalini, F. (2006). *Where Did WEEE Go Wrong in Europe ? Practical and Academic Lessons for the US*. [online] Available at: https://ieeexplore.ieee.org/document/1650039/. [Accessed 31 Mar. 2018].

International Business Times UK. (2014). *Active Mobile Phones Outnumber Humans for the First Time*. [online] Available at: https://www.ibtimes.co.uk/there-are-more-gadgets-there-are-people-world-1468947 [Accessed 28 Aug. 2018].

IDC: The premier global market intelligence company. (2018). *Apple Passes Samsung to Capture the Top Position in the Worldwide Smartphone Market While Overall Shipments Decline 6.3% in the Fourth Quarter, According to IDC*. [online] Available at: https://www.idc.com/getdoc.jsp?containerId=prUS43548018 [Accessed 11 Sep. 2018].

Ishizaka, A., Siraj, S. and Nemery, P. (2016). *Which Energy Mix for the UK (United Kingdom)? An Evolutive Descriptive Mapping with the Integrated GAIA (graphical Analysis for Interactive aid)– AHP (analytic Hierarchy Process) Visualization Tool*. Energy, 95, pp. 602-11.

iFixit, (2016). *Smartphone Repairability Scores.* [online] Available at: https://www.ifixit.com/smartphone-repairability [Accessed 12 Aug. 2016].

Ishizaka, A., Siraj, S. and Nemery, P., 2016. Which energy mix for the UK (United Kingdom)? An evolutive descriptive mapping with the integrated GAIA (graphical analysis for interactive aid)– AHP (analytic hierarchy process) visualization tool. *Energy*, 95, pp. 602-611.

Iyengar, S. S. and Lepper, M. R. (2000). When Choice is Demotivating: Can One Desire Too Much of a Good Thing? *Journal of Personality and Social Psychology*, 79, pp. 995-1006.

Jonhson, E. J., Dellaert, B. G. C., Fox, C., Goldstein, D. G., Haubl, G., Larrick, R. P., Payne, J. W., Peters, E., Schkade, D., Wansick, D., Weber, E. U. (2012). *Beyond nudges: Tools of a choice architecture*, 23, pp. 487-504.

Johnson, R. B., and Onwuegbuzie, A. J. (2004) Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher*, 33(7), pp. 14-26.

Jones, N., Evangelinos, K., Halvadakis, C. P., Losifides, T., and Sophoulis, C. M. (2010). Social Factors Influencing Perceptions and Willingness to Pay for a Market-Based Policy Aiming on Solid Waste Management. *Resources, Conservation and Recycling*, 54(9), pp. 533-40.

Kahneman, D., Knetsch, J. L. and Thaler, R. H. (1990). *Journal of Political Economy,* 98(6), pp. 1325-1348.

Kahneman, D. and Tversky, A. (1984). *Choices, Values, and Frames.* American Psychological Association, 39, pp. 341-350.

Kals, E., Schumacher, D, and Montada, L. (1999). Emotional Affinity toward Nature as a Motivational Basis to Protect Nature. *Environment and Behavior,* 31(2), pp. 178-202.

Kamenica, E. (2012). Behavioral Economics and Psychology of Incentives. *The Annual Review of Economics, Reviews in Advance*, 4, pp. 1-26.

Korea JoongAng Daily, (2011). *SERI says 'urban mines' needed for rare earths*. [online] Available at: http://koreajoongangdaily.joins.com/news/article/article.aspx?aid=2938894 [Accessed 23 Aug. 2018].

Kwok, L. (2012). Exploratory-triangulation design in mixed methods studies: A case of examining graduating seniors who meet hospitality recruiters' selection criteria. *Tourism and Hospitality Research* 12, 125–138.

Keramitsoglou, K. M., and Tsagarakis, K. P. (2013). Public Participation in Designing a Recycling Scheme towards Maximum Public Acceptance. *Resources, Conservation and Recycling*, 70(0), pp. 55-67.

Kim, S., Oguchi, M., Yoshida, A. and Terazono, A. (2013). Estimating the amount of WEEE generated in South Korea by using the population balance model. *Waste Management,* 33, pp. 474-483.

Kim, Y., Wang, Y., Oh, J. (2016). Digital Media Use and Social Engagement: How Social Media and Smartphone Use Influence Social Activities of College Students. *Cyberpsychology, Behavior, and Social Networking* 19, 264–269.

Knetsch, J. (1989). The Endowment Effect and Evidence of Nonreversible Indifference Curves. *The American Economic Review*, 79, pp. 1277-1284.

Knussen, C., Yule, F. MacKenzie, J. and Wells, M. (2004). An Analysis of Intentions to Recycle Household Waste: The Roles of Past Behaviour, Perceived Habit, and Perceived Lack of Facilities. *Journal of Environmental Psychology*, 24 (2), pp. 237-46.

Krook, J., Carlsson, A., Eklund, M., Frändegård, P. and Svensson, N. (2011). Urban Mining: Hibernating Copper Stocks in Local Power Grids*. Journal of Cleaner Production,* 19 (9-10), pp. 1052-56.

Krook, J.and Baas, L. (2013). Getting Serious about Mining the Technosphere: A Review of Recent Landfill Mining and Urban Mining Research. *Journal of Cleaner Production, Special Volume: Urban and Landfill Mining*, 55, pp. 1-9.

Kwok, L. (2012). Exploratory-triangulation design in mixed methods studies: A case of examining graduating seniors who meet hospitality recruiters' selection criteria. *Tourism and Hospitality Research*, 12, pp.125-138.

Lakhan, C. (2015). Evaluating the Effects of Unit Based Waste Disposal Schemes on the Collection of Household Recyclables in Ontario, Canada. *Resources, Conservation and Recycling,* 95, pp. 38-45.

Landeta, J., Barrutia, J. and Lertxundi, A. (2011). Hybrid Delphi: A methodology to facilitate contribution from experts in professional contexts. *Technological Forecasting and Social Change, The Delphi technique: Past, present, and future prospects*, 78, pp.1629-1641.

Lawshe, C. H. (1975). A quantitative approach to content validity. *Personnel Psychology*, 28(4), pp. 563-575.

Le Bozec, A. (2008). The Implementation of PAYT System under the Condition of Financial Balance in France. *Waste Management, Pay as you throw: a tool for urban waste management*, 28 (12), pp. 2786-92.

Le Hoang, L., Yamasue, E., Okumura, H. and Ishihara, K. (2013). Analysis of Intentions to Recycle Electronic Waste (E-Waste) Using the Theory of Planned Behavior: A Case Study in Urban Areas of Vietnam. pp.73-79.

Legislative train schedule | European Parliament. (2019). European Parliament. Retrieved 15 February 2019, from http://www.europarl.europa.eu/legislative-train/theme-new-boost-for-jobs-growth-and-investment/file-ecodesign-for-circular-economy

Lehtonen, O. and Tykkyläinen, M. (2014). Delphi Path Simulator for Unveiling Development Opportunities in the Forest Industries by Contrasting Forest Management Practices - The Case of North Karelia. *Technological Forecasting and Social Change,* 84, pp. 171-85.

Lenhart, A., Purcell, K., Smith, A., Zickuhr, K. (2010). Social Media & Mobile Internet Use among Teens and Young Adults. Millennials. Pew Internet & American Life Project.

Lerner, J., Small, D. and Loewenstein, G. (2004). Heart Strings and Purse Strings. *American Psychological Society, Psychological Science*, 15, pp. 337-342.

Li, J., Dong, Q., Liu, L. and Song, Q. (2015). Measuring Treatment Costs of Typical Waste Electrical and Electronic Equipment: A Pre-Research for Chinese Policy Making. *Waste Management*.

Lieber, E. (2009). Mixing Qualitative and Quantitative Methods: Insights into Design and Analysis Issues. *Journal of Ethnographic & Qualitative Research*, 3, pp. 218-27.

Litwin, M. S. (1995). How to measure survey reliability and validity. London: Sage Publications.

Lizin, S., Van Dael, M. and Van Passel, S. (2017). Battery pack recycling: Behaviour change interventions derived from an integrative theory of planned behaviour study. *Resources, Conservation and Recycling*, 122, pp. 66-82.

Mahmud, S. N. D. and Osman, K. (2010). The Determinants of Recycling Intention Behavior among the Malaysian School Students: An Application of Theory of Planned Behaviour. *Procedia - Social and Behavioral Sciences*, 9, pp. 119-24.

Mannetti, L., Pierro, A. and Livi, S. (2004). Recycling: Planned and self-expressive behaviour. *Journal of Environmental Psychology,* 24(2), pp. 227-236.

Manzi, S. (2015). *Understanding Waste Management Behaviour in Care Settings in South West England: A Mixed Methods Study*. [online]. Available at: https://pearl.plymouth.ac.uk//handle/10026.1/3501. [Accessed 31 Mar. 2018]

Marketsandmarkets.com, (2018). *Intelligent Virtual Assistant Market worth 17.72 Billion USD by 2023*. [online] Available at: https://www.marketsandmarkets.com/PressReleases/intelligent-virtual-assistant.asp [Accessed 21 Aug. 2018].

Martin-Collado, D., Byrne, T. J., Amer, P. R., Santos, B. F. S., Axford, M. and Pryce, J. E. (2015). Analyzing the heterogeneity of farmers' preferences for improvements in dairy cow traits using farmer typologies. *Journal of Dairy Science,* 98, pp. 4148-4161.

Massari, S., Ruberti, M. (2013). Rare earth elements as critical raw materials: Focus on international markets and future strategies. *Resources Policy* 38, 36–43.

Mayers, K., Peagam, R., France, C., Basson, L. and Clift, R. (2011). Redesigning the Camel. *Journal of Industrial Ecology*, 15, pp. 4-8.

McArthur Foundation, E. (2015). *Towards the Circular Economy*. [online]. Southampton: McKinsey & Company. Available at: http://www.ellenmacarthurfoundation.org/books-and-reports#!/Towards-the-Circular-Economy-vol-1/p/32770373/category=0.

Mertens, D. M. and Hesse-Biber, S. (2012). Triangulation and Mixed Methods Research Provocative Positions. *Journal of Mixed Methods Research*, 6 (2), pp. 75-79.

Miller, M. H. and Upton, C. W. (1976). Leasing, Buying, and the Cost of Capital Services. *The Journal of Finance*, 31, pp. 761-786.

Milovantseva, N. and Saphores, J.-D. (2013). Time Bomb or Hidden Treasure? Characteristics of Junk TVs and of the US Households Who Store Them. *Waste Management, Special Thematic Issue: Urban Mining Urban Mining*, 33(3), pp. 519-29.

Mitchell, G. (2005). Libertarian Paternalism Is an Oxymoron. *Nortwestern University Law Review,* 99, pp. 1-42.

Morewedge, C. K., Shu, L. L., Gilbert, D. T. and Wilson, T. D. (2009). Bad riddance or good rubbish? Ownership and not loss aversion causes the endowment effect. *Journal of Experimental Social Psychology,* 45, pp. 947-951.

Morgan, D. L. (2007). Paradigms Lost and Pragmatism Regained Methodological Implications of Combining Qualitative and Quantitative Methods. *Journal of Mixed Methods Research,* 1 (1), pp. 48-76.

Mueller, S. R., Wäger, P. A., Turner, D. A., Shaw, P. J. and Williams, I. D. (2017). A framework for evaluating the accessibility of raw materials from end-of-life products and the Earth's crust. *Waste Management,* 68, pp. 534-546.

Nardi, P. M. (2013). Doing Survey Research. Boulder. London: Routledge, 3rd Edition.

Nayak, J. K. (2018). Relationship among smartphone usage, addiction, academic performance and the moderating role of gender: A study of higher education students in India. *Computers & Education*, 123, pp. 164-173.

Nielsen, H. M., Amer, P. R., and Byrne, T. J. (2014). Approaches to formulating practical breeding objectives for animal production systems. *Acta Agriculturae Scandinavica, Section A - Animal Science,* 64, pp. 2-12.

Nixon, H. and Saphores, J.-D. M. (2007). Financing Electronic Waste Recycling Californian Households' Willingness to Pay Advanced Recycling Fees. *Journal of Environmental Management*, 84 (4) pp. 547-59.

NobelPrize.org, (2018). *Daniel Kahneman - Facts - NobelPrize.org.* [online] Available at: https://www.nobelprize.org/prizes/economics/2002/kahneman/facts/ [Accessed 12 Sep. 2018].

Nduneseokwu, C., Qu, Y., Appolloni, A., Nduneseokwu, C.K., Qu, Y., Appolloni, A. (2017). Factors Influencing Consumers' Intentions to Participate in a Formal E-Waste Collection System: A Case Study of Onitsha, Nigeria. Sustainability 9, 881.

Oecd.org, (2018). *From Crisis to Recovery - OECD.* [online] Available at: https://www.oecd.org/insights/fromcrisistorecovery.htm [Accessed 30 Aug. 2018].

Oguchi, M., Kameya, T., Yagi, S. And Urano, K. (2008). Product flow analysis of various consumer durables in Japan. *Resources, Conservation and Recycling,* 52, pp. 463-480.

Ojedokun, O. Attitude towards Littering as a Mediator of the Relationship between Personality Attributes and Responsible Environmental Behavior*. Waste Management,* 31 (12) pp. 2601-11.

Oko-Institut (2011). *Study on Rare Earths and Their Recycling. Final Report for The Greens/EFA Group in the European Parliament*. [online] Strasbourg: European Parliament. Available at: http://www.oeko.de/oekodoc/1112/2011-003-en.pdf [Accessed 31 Mar. 2018].

Ongondo, F. O. and Williams, I. D. (2011). Greening Academia: Use and Disposal of Mobile Phones among University Students*. Waste Management,* 31(7), pp. 1617-34.

Ongondo, F. O. and Williams, I. D. (2011). Mobile Phone Collection, Reuse and Recycling in the UK. *Waste Management,* 31(6), pp. 1307-15.

Ongondo, F. O., Williams, I.D. and Cherrett, T. J. (2011). How Are WEEE Doing? A Global Review of the Management of Electrical and Electronic Wastes. *Waste Management (New York, N.Y.),* 31(4), pp. 714-30.

Ongondo, F. O., Williams, I. D., Dietrich, J. and Carroll C. (2013). ICT Reuse in Socio-Economic Enterprises. *Waste Management*, 33(12), pp. 2600-2606.

Ongondo, F. O., Williams, I. D. and Keynes, S. (2011). Estimating the Impact of the "Digital Switchover" on Disposal of WEEE at Household Waste Recycling Centres in England. *Waste Management (New York, N.Y.),* 31(4), pp. 743-53.

Ongondo, F. O., Williams, I. D. and Whitlock, G. (2015). Distinct Urban Mines: Exploiting Secondary Resources in Unique Anthropogenic Spaces. *Waste Management, Urban Mining*, 45, pp. 4-9.

Ongondo, F. (2011). *PhD Thesis: Factors That Influence the Generation, Collection and Disposal of Waste Electrical Equipment*. University of Southampton.

Onwuegbuzie, A. J., Bustamante, R. M. and Nelson, J. A. (2010). Mixed Research as a Tool for Developing Quantitative Instruments. *Journal of Mixed Methods Research,* 4(1), pp. 56-78.

Oswald, I. and Reller, A. (2011). E-Waste: A Story of Trashing, Trading, and Valuable Resources.

Pakpour, A. H., Zeidi I. M., Emamjomeh, M. M., Asefzadeh, S. and Pearson H. Household Waste Behaviours among a Community Sample in Iran: An Application of the Theory of Planned Behaviour. *Waste Management, Waste Management on Asia,* 34 (6), pp. 980-86.

Pelletier, J. E., Laska, M. N., Neumark-Sztainer, D., Story, M. (2013). Positive Attitudes toward Organic, Local, and Sustainable Foods Are Associated with Higher Dietary Quality among Young Adults*. Journal of the Academy of Nutrition and Dietetics,* 113, pp. 127-132.

Pérez-Belis, V., Bovea, M. D., Ibáñez-Forés, V. (2015). An in-depth literature review of the waste electrical and electronic equipment context: trends and evolution. *Waste Management,* 33, pp. 3-29.

Perugini, M. and Bagozzi, R. P. (2001). The Role of Desires and Anticipated Emotions in Goal-Directed Behaviours: Broadening and Deepening the Theory of Planned Behaviour. *British Journal of Social Psychology,* 40(1), pp. 79-98.

Pierron, X., Williams, I., Shaw, P., Ongondo, F., Cleaver, C., 2016. *Using Choice Architecture to exploit a University Distinct Urban Mine*, In: Eurowaste, 3rd international symposium on urban mining: Bergamo, Italy, 23-25 May 2016

Pierron, X., Williams, I. Shaw, P, 2015. *The potential for developing urban mines from household stockpiled small WEEE*. In: Eurowaste, 15th International symposium on waste management. S. Margherita di Pula, Italy, 05-09 October 2015

Pierron, X., Williams, I., Shaw, P., Ongondo, F., Cleaver, C., 2014. *The potential for recovering metals from small household appliances*, In: Eurowaste, 2nd international symposium on urban mining: Bergamo, Italy, 22-24 May 2014

Plano Clark, V., Huddleston-Casas, C., O'Neil Green, D. and Garett, A. (2008). Mixed Methods Approaches in Family Science Research, *Journal of Family Issues*, pp. 1543-1566

Prior, T., Giurco, D., Mudd, G., Mason, L. and Behrisch, J. (2012). Resource depletion, peak minerals and the implications for sustainable resource management. *Global Environmental Change, Global transformations, social metabolism and the dynamics of socio-environmental conflicts,* 22, pp. 577-587.

Ramayah, T., Lee, J. W. C. and Lim, S. (2012). Sustaining the Environment through Recycling: An Empirical Study. *Journal of Environmental Management,* 102, pp. 141-47.

Ramesh, A., Prakash, G., Sekhar, C., Patwardhan, M. and Vyas, V. (2015). Operations Management in Digital Economy, A Delphi-AHP-TOPSIS Based Framework for the Prioritization of Intellectual Capital Indicators: A SMEs Perspective. *Procedia - Social and Behavioral Sciences,* 189, pp. 275-84.

Raut, R.D., Kharat, M.G., Kamble, S.S., Kamble, S.S., Kamble, S.S., Kamble, S.S., Kamble, S.S., Kamble, S.J. (2016). The application of Delphi and AHP method in environmentally conscious solid waste treatment and disposal technology selection. *Management of Env Quality* 27, 427–440.

Recycling Today, Rare opportunity to recycle rare. [online] Available at: http://www.recyclingtoday.com/article/rare-earth-metals-recycling/ [Accessed 9 Jul. 2018].

Read, A. D. (1999). “A Weekly Doorstep Recycling Collection, I Had No Idea We Could!”: Overcoming the Local Barriers to Participation. *Resources, Conservation and Recycling*, 26(3-4), pp. 217-49.

Resource depletion, peak minerals and the implications for sustainable resource management. (2012). *Global Environmental Change*, 22, pp. 577-587.

Richetin, J., Sengupta, A., Perugini, M., Adjali, I.,Hurling, R., Greetham, D. and Spence, M. (2010). A Micro-Level Simulation for the Prediction of Intention and Behavior. *Cognitive Systems Research*, 11(2), pp. 181-93.

Robinson, B. H. (2009). E-Waste: An Assessment of Global Production and Environmental Impacts. *The Science of the Total Environment,* 408(2), pp. 183-91.

Rohit, J., Banwet, D. K., and Shankar, R. (2011). A Delphi-AHP-TOPSIS Based Benchmarking Framework for Performance Improvement of a Cold Chain. *Expert Systems with Applications,* 38(8), pp. 10170-82.

Saaty, T. (2008). Decision Making with the Analytic Hierarchy Process. *Int. J. Services Sciences*, 1(1), pp. 83-98.

Saaty, T. L. (2013). The Modern Science of Multicriteria Decision Making and Its Practical Applications: The AHP/ANP Approach. *Operations Research*, 61(5), pp. 1101-18.

Sabbaghi, M., Esmaeilian, B., Mashhadi, A. R., Behdad, S. and Cade, W. (2015). An investigation of used electronics return flows: A data-driven approach to capture and predict consumers storage and utilization behavior. *Waste Management*, 36, pp. 305-315.

Salhofer, S., Steuer, B., Ramusch, R. and Beigl, P. (2015). WEEE Management in Europe and China – A Comparison. *Waste Management*.

Samuelson, W. and Zeckhauser, R. (1988). Status quo bias in decision making. *J Risk Uncertainty,* 1, pp. 7-59.

Saphores, J.-D. M., Nixon, H., Ogunseitan, O. A. and Shapiro, A. A. (2009). How much e-waste is there in US basements and attics? Results from a national survey. *Journal of Environmental Management*, 90, pp. 3322-3331.

Schultz, P.W., Oskamp, S., Mainieri, T. (1995). Who recycles and when? A review of personal and situational factors. Journal of Environmental Psychology 15, 105–121.

Schwartz, S. H. (1968). Awareness of Consequences and the Influence of Moral Norms on Interpersonal Behavior. *Sociometry,* 31(4), pp. 355-69.

Seacat, J. D. and Northrup, D. (2010). An Information–motivation–behavioral Skills Assessment of Curbside Recycling Behavior. *Journal of Environmental Psychology,* 30(4), pp. 393-401.

See-To, E. W. K. and Ho, K. K. W. (2016). A Study on the Impact of Design Attributes on E-Payment Service Utility. *Information & Management*, 53(5), pp. 668-81.

Shaw, P. J. and Maynard, S. J. (2008). The potential of financial incentives to enhance householders' kerbside recycling behaviour*. Waste Management*, 28, pp. 1732-1741.

Silveira, G. T. R. and Chang, S.-Y. (2010). Cell Phone Recycling Experiences in the United States and Potential Recycling Options in Brazil. *Waste Management (New York, N.Y.),* 30(11), pp. 2278-91.

Simoni, M., Kuhn, E. P., Morf, L. S., Kuendig, R. and Adam, F. (2015). Urban Mining as a Contribution to the Resource Strategy of the Canton of Zurich*. Waste Management, Urban Mining*, 45, pp. 10-21.

Singh, J., and Ordoñez, I. (2015). Resource Recovery from Post-Consumer Waste: Important Lessons for the Upcoming Circular Economy. *Journal of Cleaner Production*.

Smith, K. F., Ludemann, C., Lewis, C. D., Malcolm, B., Banks, R. G., Jacobs, J. L., Fennessy, P. F. and Spangenberg, G. C. (2014). Estimating the value of genetic gain in perennial pastures with emphasis on temperate species. *Crop. Pasture Sci*., 65, pp. 1230-1237.

Smith, N. C., Goldstein, D. G. and Johnson, E. J., (2013). Choice Without Awareness: Ethical and Policy Implications of Defaults. *American Marketing Association,* 32, pp. 159-172.

Sobin, C., Raychoudhury, V., Marfia, G., Singla, A. (2016). A survey of routing and data dissemination in Delay Tolerant Networks. *Journal of Network and Computer Applications* 67, 128–146.

Song, Q., Li, J. (2015). A review on human health consequences of metals exposure to e-waste in China. *Environmental Pollution* 196, 450–461.

Song, Q., Wang, Z. and Li, J. (2012). Residents' Behaviors, Attitudes, and Willingness to Pay for Recycling E-Waste in Macau. *Journal of Environmental Management*, 106, pp. 8-16.

Stahel, W. (1977). *The potential for substituting manpower for energy: Final report 30 July 1977 for the Commission of the European Communities*. [online]. Battelle: Geneva Research Centre, [Accessed 31 Mar. 2018].

Steinert, M. (2009). A Dissensus Based Online Delphi Approach: An Explorative Research Tool. *Technological Forecasting and Social Change*, 76 (3), pp. 291-300.

Step Initiative (2014). *Solving the E-Waste Problem (Step)*. [online]. United Nations University. Available at: http://www.step-initiative.org/files/step/_documents/StEP_WP_One%20Global%20Definition%20of%20E-waste_20140603_amended.pdf [Accessed 31 Mar. 2018].

Strahilevitz, M. and Loewenstein, G. (1998). The Effect of Ownership History on the Valuation of Objects. *Journal of Consumer Research*, 25, pp. 276-289.

Strömberg, H., Rexfelt, O., Karlsson, I. C. M. and Sochor, J. (2016). Trying on Change – Trialability as a Change Moderator for Sustainable Travel Behaviour. *Travel Behaviour and Society*, 4, pp. 60-68.

Su, B., Heshmati, A., Geng, Y. and Yu, X. (2013). A Review of the Circular Economy in China: Moving from Rhetoric to Implementation*. Journal of Cleaner Production*, 42, pp. 215-27.

Sunstein, C. R. and Thaler, H. R (2012). *Nudge: Improving Decisions About Health, Wealth and Happiness.* Penguin.

Sun, Z., Xiao, Y., Agterhuis, H., Sietsma, J. and Yang, Y. (2016). Recycling of Metals from Urban Mines – a Strategic Evaluation. *Journal of Cleaner Production,* 112 (4), pp. 2977–87.

Sustainability.asda.com, (2018). *Customer | Asda Sustainability*. [online] Available at: https://sustainability.asda.com/customer [Accessed 11 Sep. 2018].

Swami, V., Chamorro-Premuzic, T., Snelgar, R. and Furnham, A. (2011). Personality, Individual Differences, and Demographic Antecedents of Self-Reported Household Waste Management Behaviours. *Journal of Environmental Psychology*, 31 (1), pp. 21-26.

Tang, Y., Sun, H., Yao, Q. and Wang, Y. (2014). The Selection of Key Technologies by the Silicon Photovoltaic Industry Based on the Delphi Method and AHP (analytic Hierarchy Process): Case Study of China. *Energy,* 75, pp. 474-82.

Terazono, A., Oguchi, M., Iino, S. and Mogi, S. (2015). Battery collection in municipal waste management in Japan: Challenges for hazardous substance control and safety. *Waste Management*, 39, pp. 246-257.

Tesco plc., (2018). *Waste and recycling in the UK*. [online] Available at: https://www.tescoplc.com/little-helps-plan/reports-and-policies/recycling-in-the-uk/ [Accessed 28 Aug. 2018].

Thaler, R. (1980). Toward a Positive Theory of Consumer Choice. *Journal of Economic Behavior and Organization,* 1, pp. 39-60.

Thaler, R. H. and Sunstein, C. R. (2003). Libertarian Paternalism. *The American Economic Review*, 93, pp. 175-179.

Thaler, R. H. and Sunstein, C. R. (2008). Nudge: Improving Decisions about Health, Wealth, and Happiness. Yale University Press.

Thaler, R. H., Sunstein, C. R. and Balz, J. P. (2014). Choice Architecture. *In The Behavioral Foundations of Public Policy*, pp. 428-39. Eldar Shafir. [online] Available at: http://papers.ssrn.com/sol3/Papers.cfm?abstract_id=2536504. [Accessed 31 Mar. 2018].

The Economist - 1843, (2016). *The scientists who make apps addictive*. [online] Available at: https://www.1843magazine.com/features/the-scientists-who-make-apps-addictive [Accessed 29 Mar. 2017].

The Independent. (2014). *There are officially more mobile devices than people in the world*. [online] Available at: https://www.independent.co.uk/life-style/gadgets-and-tech/news/there-are-officially-more-mobile-devices-than-people-in-the-world-9780518.html [Accessed 7 Feb. 2019].

Timlett, R. E. and Williams, I. D. (2008). Public Participation and Recycling Performance in England: A Comparison of Tools for Behaviour Change. *Resources, Conservation and Recycling*, 52(4), pp. 622-34.

Tompson, S., Lieberman, M. D. and Falk, E. B. (2015). Grounding the Neuroscience of Behavior Change in the Sociocultural Context. *Current Opinion in Behavioral Sciences, Neuroeconomics*, 5, pp. 58-63.

Tonglet, M., Phillips, P. S. and Read, A. D. (2004). Using the Theory of Planned Behaviour to Investigate the Determinants of Recycling Behaviour: A Case Study from Brixworth, UK. Resources, Conservation and Recycling 41(3), pp. 191-214.

Tonglet, M., Phillips, P. S. and Bates, M. P. (2004). Determining the Drivers for Householder pro-Environmental Behaviour: Waste Minimisation Compared to Recycling. *Resources, Conservation and Recycling*, 42(1), pp. 27-48.

Toyota, *'Vehicle Recycling'. Environmental Affairs Division*. (2014), [online] Japan: Toyota Motor Corporation, 2014. http://www.toyota-global.com/sustainability/report/vehicle_recycling/pdf/vr_all.pdf. [Accessed 31 Mar. 2018].

Tunsu, C., Petranikova, M., Gergorić, M., Ekberg, C, and Retegan, T. (2015). Reclaiming Rare Earth Elements from End-of-Life Products: A Review of the Perspectives for Urban Mining Using Hydrometallurgical Unit Operations. *Hydrometallurgy,* 156, pp. 239-58.

Tversky, A. and Kahneman, D. (1981). The Framing of Decisions and the Psychology of Choice. *Science,* 211, pp. 453-458.

Tversky, A., Kahneman, D. (1991). Loss Aversion in Riskless Choice: A Reference-Dependent Model. *The Quarterly Journal of Economics*, 106, pp. 1039-1061.

Tversky, A. and Kahneman, D. (1992). Advances in Prospect Theory: Cumulative Representation of Uncertainty. *Journal of Risk and Uncertainty,* 5(4), pp. 297-323.

Udawatta, N., Zuo, J., Chiveralls, K. and Zillante, G. (2015). Improving Waste Management in Construction Projects: An Australian Study. *Resources, Conservation and Recycling,* 101, pp. 73-83.

UNEP, (2011). *Manual 3: WEEE / E-Waste "Take Back System"*. [online] Germany: United Nations Environment Programme. Available at: http://www.unep.org/ietc/Portals/136/Events/WEEE-E%20workshop%20July%202011/UNEP_Ewaste_Manual3_TakeBackSystem.pdf [Accessed 31 Mar. 2018].

Unfccc.int., (2018). *The Paris Agreement | UNFCCC*. [online] Available at: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement [Accessed 22 Aug. 2018].

United Nations University, (2017). *The Global E-waste Monitor.* [online] Available at: https://collections.unu.edu/eserv/UNU:6341/Global-E-waste_Monitor_2017__electronic_single_pages_.pdf [Accessed 21 Aug. 2018].

Urban Mining, (2011). *SERI Says "Urban Mines" Needed for Rare Earths | Urbanmining*. [online] Available at: http://urbanmining.org/2011/07/seri-urban-mines-rare-earths. [Accessed 31 Mar. 2018].

US Department of Energy, (2010). *Critical Materials Strategy*. [online] Washington, DC: US Department of Energy. Available at: http://energy.gov/sites/prod/files/edg/news/documents/criticalmaterialsstrategy.pdf [Accessed 31 Mar. 2018].

US EPA. OSWER, (2014). *'Advancing Sustainable Materials Management: Facts and Figures'*. [online] Collections and Lists. Available at: https://www.epa.gov/smm/advancing-sustainable-materials-management-facts-and-figures. [Accessed 31 Mar. 2018].

US EPA. (2013). *Reducing and Reusing Basics | US EPA*. [online] Available at: https://www.epa.gov/recycle/reducing-and-reusing-basics [Accessed 28 Aug. 2018].

Varmazyar, M., and Nouri, B. (2014). A Fuzzy AHP Approach for Employee Recruitment. *Decision Science Letters*, 3(1), pp. 27-36.

Vassanadumrongdee, S., Kittipongvises, S. (2018). Factors influencing source separation intention and willingness to pay for improving waste management in Bangkok, Thailand. Sustainable Environment Research 28, 90–99.

Walls, M. (2013). *'Deposit-Refund Systems in Practice and Theory'. In Encyclopedia of Energy, Natural Resource, and Environmental Economics, edited by Jason F. Shogren,* pp. 133-37. [online] Waltham: Elsevier, Available at. http://www.sciencedirect.com/science/article/pii/B9780123750679000358. [Accessed 31 Mar. 2018].

Wallsten, B., Magnusson, D., Andersson, S. and Krook, J. (2015). The Economic Conditions for Urban Infrastructure Mining: Using GIS to Prospect Hibernating Copper Stocks. *Resources, Conservation and Recycling*, 103, pp. 85-97.

Wan, C., Shen, G. and Yu, A. (2014), The Moderating Effect of Perceived Policy Effectiveness on Recycling Intention. *Journal of Environmental Psychology*, 37, pp. 55-60.

Wan, C., Shen, G. and Yu, A. (2014). The Role of Perceived Effectiveness of Policy Measures in Predicting Recycling Behaviour in Hong Kong. *Resources, Conservation and Recycling,* 83, pp. 141-51.

Welfens, M. J., Nordmann, J. and Seibt, A. (2016). Drivers and barriers to return and recycling of mobile phones. Case studies of communication and collection campaigns. *Journal of Cleaner Production, Absolute Reductions in Material Throughput, Energy Use and Emissions,* 132, pp. 108-121.

Werner, C. M.  (2003). 'Changing Homeowners' Use of Toxic Household Products: A Transactional Approach. *Journal of Environmental Psychology*, 23(1). pp. 33-45.

Wilson, G.T., Smalley, G., Suckling, J.R., Lilley, D., Lee, J., Mawle, R. (2017). The hibernating mobile phone: Dead storage as a barrier to efficient electronic waste recovery. *Waste Management, Special Thematic Issue: Urban Mining and Circular Economy* 60, 521–533.

WRAP, (2013). *'Increase Your Small WEEE Collection Rates | WRAP UK'*. [online] Available at: http://www.wrap.org.uk/content/increase-your-small-weee-collection-rates. [Accessed 31 Mar. 2018].

Wright, M. (2015). *'How the Circular Economy Is Taking off in the US'*. [online] The Guardian, 2015, sec. Guardian Sustainable Business. Available at: https://www.theguardian.com/sustainable-business/2015/aug/26/how-the-circular-economy-is-taking-off-in-the-us. [Accessed 31 Mar. 2018].

WTO. (2014). *'China - Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum'*. [online] Switzerland: World Trade Organisation, Available at: https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds431_e.htm. [Accessed 31 Mar. 2018].

Yao, R. and Steemers, k. (2009). Overview of an Innovative EU–China Collaboration in Education and Research in Sustainable Built Environment. *Renewable Energy, Special Issue: Building and Urban Sustainability*, 34 (9), pp. 2080-87.

Yeh, D. -Y., and Cheng, C. -H. (2015). Recommendation System for Popular Tourist Attractions in Taiwan Using Delphi Panel and Repertory Grid Techniques. *Tourism Management*, 46, pp. 164-76.

Yin, J., Gao, Y. and Xu, H. (2014). 'Survey and Analysis of Consumers' Behaviour of Waste Mobile Phone Recycling in China. *Journal of Cleaner Production,* 65(0), pp. 517-25.

Ylä-Mella, J., Keiski, R.L., Pongrácz, E., (2015). Electronic waste recovery in Finland: Consumers' perceptions towards recycling and re-use of mobile phones. *Waste Management, Urban Mining* 45, 374–384.

Ylä-Mella, J., Poikela, K., Lehtinen, U., Keiski, R. L., and Pongrácz, E. (2014). Implementation of Waste Electrical and Electronic Equipment Directive in Finland: Evaluation of the collection network and challenges of the effective WEEE management. *Resources, Conservation and Recycling,* 86, pp. 38-46.

Yoada, R. M., Chirawurah, D. and Adongo, P. B. (2014). Domestic Waste Disposal Practice and Perceptions of Private Sector Waste Management in Urban Accra. *BMC Public Health,* 14, pp. 697.

Zangenehmadar, Z., and O. Moselhi. (2016). Prioritizing Deterioration Factors of Water Pipelines Using Delphi Method. *Measurement,* 90, pp. 491-99.

Zen, I. S., Noor, Z. Z. and Yusuf, R. O. (2014). The Profiles of Household Solid Waste Recyclers and Non-Recyclers in Kuala Lumpur, Malaysia. *Habitat International*, 42(0), pp. 83-89.

Zen, I. S. and Siwar, C. (2015). An analysis of household acceptance of curbside recycling scheme in Kuala Lumpur, Malaysia. *Habitat International,* 47, pp. 248-255.

Zhang, K. and Kleit, A. N. (2016). Mining Rate Optimization Considering the Stockpiling: A Theoretical Economics and Real Option Model. *Resources Policy*, 47, pp. 87-94.

Zhong, H. and Zhao, C. (2012). E-waste Deposit system under EPR in China: A view from closed-loop supply chain. *ICSSSM12, Shanghai*, pp. 239-243.

# Appendix A Delphi data collection ethics approval message

On 11 May 2015, at 15:55, ERGO <ergo@soton.ac.uk> wrote:

Submission Number: 12419

Submission Name: Qualitative data collection

This is email is to let you know your submission was approved by the Ethics Committee.

Comments

1.The study seems fine but you seem to have an overly complicated approach to obtaining consent. If Ian Williams is going to get preliminary consent from the potential experts, then it isn't necessary to send them a paper consent form as well. You can put the important parts of the consent form (boxes 1-3) at the top of the survey monkey questionnaire and provide a small box for people to tick before they move on to the survey itself. Note that if you do decide to use the full consent form, you should remove the last comment and box (as the university actually has no such database). Please also note that your Participant Information Sheet needs correct information for the penultimate bullet ('what happens if something goes wrong?'). Good luck.

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ERGO: Ethics and Research Governance Online

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DO NOT REPLY TO THIS EMAIL

# Appendix B Message to invite participants to Delphi round one

Dear xxx,

Two weeks ago, Professor Ian Williams contacted you as an expert in the field of waste management. He asked for your kind participation in an online study on end-of-use e-waste behaviour. My name is Xavier Pierron and I am working with Ian and other colleagues from the Centre of Environmental Science to better understand users' decision-making process when parting from mobile touchscreen devices, such as smart phones and tablets. We understand you might be busy at this time of the year but we would very much value your expertise on this topic.

We have designed the survey following a Delphi data collection methodology. This is the first stage of the process. Early responses show that participants have taken on average 10 minutes to complete the survey. Then to form a consensus among panel members, a second round will be organised in September, also using an online asynchronous method. If you participated in this 2-round study, as a sign of gratitude we would be happy to share our results with you.

I have included the survey link here below and the deadline for completion would be Monday 20th of July. We would be very appreciative of your input to this study.

https://www.surveymonkey.com/r/L7923M7

Please let me know if you have any questions.

Thank you for your attention,

Xavier Pierron

PhD researcher

# Appendix C Delphi round one Participant Information Sheet and questionnaire

## End of use mobile touchscreen devices decisions

Welcome to the end of use mobile touchscreen devices decisions survey

**As a thank you, you will receive asummary report once the data collection is completed.**

**The questionnaire will require approximately 20' of your time and we ask a turnaround time of 4 weeks. We might contact you after 2 weeks of receiving this invitation if you haven't responded yet. We are collecting waste management experts opinion on household reuse, recycle and discard decisions for mobile touchscreen devices. Once all data is completed, a second round will be offered to existing participants - and another summary report will be sent. If you are interested, you will be contacted again in September for the second round. You are free not to accept the second round or to drop from the survey at any time.**

**a. Before starting this survey, we invite you to read the following guidance:**
**Mobile touchscreen devices (smart phones, mini-tablets, tablets) have been targeted (excluding mobile phones) as the range and depth of interactions with the devices are wider and deeper than with regular mobile phones. Laptops, PCs and other computing devices have been excluded due to their limited mobility compared to mobile touchscreen devices, and inherent restricted range of interactions.**
**It is assumed the interaction process has an influence over the end of use decision-making process.**

**b. Statements are being made and we ask you toagree or disagree using a 5-point Likert scale.**

**c. Factors have been selected from waste management research, behavioural economics and other relevant variables identified from the academic literature. Four decision categories over four pages have been created: 1. reusing / reselling; 2. reusing / giving away; 3. recycling and finally 4. discarding. Across categories there might be similar questions as some factors can be applied to any of these categories.**

**d. If some terms are unclear, such as moral norms or altruism, you can click on the word hyperlink in the question to access the definition.**

**e. If you have any questions, please contact Xavier Pierron xp1v12@soton.ac.uk or at 07557 425 134.**

**f. Thank you very much for your time and expertise on this subject.**
**The survey is about to begin, we just need your consent on the following items.**
**Please note that any "no" answer will prevent the survey to be initiated. You are free to drop from the survey at any time without any prior agreement. We nonetheless hope you will find the process interesting and that you will find value to receive the data collection report.**

* 1. I have read and understood the information sheet attached to the email with the survey link (study #: 11052015/1) and have had the opportunity to ask questions about the study.

◯ Yes

◯ No

* 2. I agree to take part in this research project and agree for my data to be used for the purpose of this study.

◯ Yes

◯ No

* 3. I understand my participation is voluntary and I may withdraw at any time without my legal rights being affected.

◯ Yes

◯ No

* 4. I understand that information collected about me during my participation in this study will be stored on a password protected computer and that this information will only be used for the purpose of this study. All files containing any personal data will be made anonymous.

◯ Yes

◯ No

## End of use mobile touchscreen devices decisions

### END OF USE RESELLING DECISIONS

5. Please agree or disagree with the following statements.

| | 1. Strongly agree | 2. Agree | 3. Neutral | 4. Disagree | 5. Strongly disagree |
|---|---|---|---|---|---|
| When deciding to resell their device, users might feel parting from it as an emotional loss. The economic benefit does not compensate the feeling of loss. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device is more useful as a spare, better not to resell it. | ◯ | ◯ | ◯ | ◯ | ◯ |

| | 1. Strongly agree | 2. Agree | 3. Neutral | 4. Disagree | 5. Strongly disagree |
|---|---|---|---|---|---|
| The device perceived usefulness is higher than its market value; better not to resell it and keep it at home as a spare. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users might not resell their device as once it is sold the decision is irreversible. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The reselling process is cumbersome, better not to resell the device and store it at home. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Reselling this type of device is not convenient. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Reselling this type of device is time consuming. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Reselling this type of device is costly. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users have a limited experience in electronic product reselling. They tend not to resell this type of device. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users have a limited awareness of existing reselling opportunities for this type of device. | ◯ | ◯ | ◯ | ◯ | ◯ |
| There could be a more convenient opportunity in the future to resell this type of device; better to store it at home. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device size being limited, storing it instead of reselling it is not an issue. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device size being limited, the reselling process appears cumbersome and it is easier to store it. | ◯ | ◯ | ◯ | ◯ | ◯ |

| | 1. Strongly agree | 2. Agree | 3. Neutral | 4. Disagree | 5. Strongly disagree |
|---|---|---|---|---|---|
| The device size being limited, storing it for a potential later use is more useful than reselling it. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users tend to resell this type of device one at a time. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users tend to resell their device immediately after acquiring a new one. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Slightly obsolete devices tend to be resold. | ◯ | ◯ | ◯ | ◯ | ◯ |

Please list any other factors that could prevent reselling mobile touchscreen devices. This box can be left empty.

## End of use mobile touchscreen devices decisions

REUSING DECISIONS

6. Please agree or disagree with the following statements.

| | 1. Strongly agree | 2. Agree | 3. Neutral | 4. Disagree | 5. Strongly disagree |
|---|---|---|---|---|---|
| When deciding to give away the device, users might feel parting from it as an emotional loss. The positive feeling associated to the act of giving does not overcome the sensation of loss. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device is more useful as a spare, better not to give it away. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device perceived usefulness is higher than the emotional reward if given away; better to keep it at home as a spare. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users might decide not to give away their device as they might regret it later. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device size being limited, storing it instead of giving it is not an issue. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device size being limited, storing it for a potential later use is more useful than giving it away. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users tend to give this type of device away one at a time. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users tend to give their device away immediately after acquiring a new one. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Slightly obsolete devices tend to be given away. | ◯ | ◯ | ◯ | ◯ | ◯ |

Please list any other factors that could prevent giving away mobile touchscreen devices. This box can be left empty.

## End of use mobile touchscreen devices decisions

RECYCLING DECISIONS

7. Please agree or disagree with the following statements.

| | 1. Strongly agree | 2. Agree | 3. Neutral | 4. Disagree | 5. Strongly disagree |
|---|---|---|---|---|---|
| When deciding to recycle their device, users might feel parting from it as an emotional loss. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users might decide not to recycle their device as once the device is sent to recycling the decision is irreversible. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device usefulness is higher as a backup or spare, better not to recycle it and store it at home. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The recycling information gathering process is complex, better not to recycle the device and store it at home. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users lack of a positive attitude towards recycling this type of device. | ◯ | ◯ | ◯ | ◯ | ◯ |
| There is a lack of social pressure to recycle this type of device. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users lack of environmental values, thus they don't recycle this type of device. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users lack of ethical values, thus they don't recycle this type of device. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users lack of altruistic values, thus they don't recycle this type of device. | ◯ | ◯ | ◯ | ◯ | ◯ |

| | 1. Strongly agree | 2. Agree | 3. Neutral | 4. Disagree | 5. Strongly disagree |
|---|---|---|---|---|---|
| Recycling this type of device is not convenient. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Recycling this type of device is time consuming. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Recycling this type of device is costly. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users have a limited experience in electronic waste recycling, thus tend not to recycle this type of device. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users have a limited experience in recycling household waste, thus tend not to recycle this type of device. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users have a limited awareness of existing recycling opportunities for this type of device. | ◯ | ◯ | ◯ | ◯ | ◯ |
| There could be a more convenient opportunity in the future to recycle this type of device; better to store it at home in the meantime. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device size being limited, storing it instead of recycling it is not an issue. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device size being limited, the recycling process appears cumbersome and it is more convenient to store it at home. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device size being limited, storing it for a potential later use is more useful than recycling it. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users tend not to recycle unbroken (still working) devices. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users tend to recycle several devices at once, instead of one at a time. | ◯ | ◯ | ◯ | ◯ | ◯ |

| | 1. Strongly agree | 2. Agree | 3. Neutral | 4. Disagree | 5. Strongly disagree |
|---|---|---|---|---|---|
| Users tend to recycle their device after being stored for a significant amount of time. | ◯ | ◯ | ◯ | ◯ | ◯ |
| If the device has still some usefulness for the user, it will not be recycled. | ◯ | ◯ | ◯ | ◯ | ◯ |

Please list any other factors that could prevent recycling mobile touchscreen devices. This box can be left empty.

## End of use mobile touchscreen devices decisions

### DISCARDING DECISIONS

8. Please agree or disagree with the following statements.

| | 1. Strongly agree | 2. Agree | 3. Neutral | 4. Disagree | 5. Strongly disagree |
|---|---|---|---|---|---|
| The device size being limited, it is more convenient to discard it in the general refuse. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users tend to discard their device after being stored for a significant amount of time. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Too many devices have been stored at home, now it is time to get rid of them. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Device has not been used as backup or spare as initially hoped. Its usefulness is close to nothing and should be discarded. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Recycling this type of device is cumbersome, it is simpler to discard them. | ◯ | ◯ | ◯ | ◯ | ◯ |

| | 1. Strongly agree | 2. Agree | 3. Neutral | 4. Disagree | 5. Strongly disagree |
|---|---|---|---|---|---|
| Users lack of a positive attitude towards recycling, they simply tend to discard what they don't recycle. | ◯ | ◯ | ◯ | ◯ | ◯ |
| There is a lack of social pressure if this type of device is discarded. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Nobody knows if this type of device is being discarded, it is acceptable to discard it in the general refuse. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users lack of environmental values, they tend to discard this type of device instead of recycling them. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users lack of ethical values, they tend to discard this type of device instead of recycling them. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users lack of altruistic values, they tend to discard this type of device instead of recycling them. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Discarding this type of device in the general refuse is convenient. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Discarding this type of device in the general refuse is time saving. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Discarding this type of device in the general refuse is economically efficient from a personal perspective. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Users have limited experience in electronic waste recycling, they simply tend to discard this type of device. | ◯ | ◯ | ◯ | ◯ | ◯ |
| The device has been stored for a large amount of time and now needs to be discarded. | ◯ | ◯ | ◯ | ◯ | ◯ |

| | 1. Strongly agree | 2. Agree | 3. Neutral | 4. Disagree | 5. Strongly disagree |
|---|---|---|---|---|---|
| The closer the device usefulness is to 0, the more likely it will be discarded. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Obsolete devices tend to be more recycled than discarded. | ◯ | ◯ | ◯ | ◯ | ◯ |
| Very obsolete devices tend to be more often discarded than recycled. | ◯ | ◯ | ◯ | ◯ | ◯ |

Please identify any other factors that could tempt users to discard their mobile touchscreen devices. This box can be left empty.

## End of use mobile touchscreen devices decisions

Generic information

9. Before finishing this survey please fill in some information. All information collected will remain confidential.

**Name**

**Company**

**Postcode**

10. Years of experience in the waste management industry

## End of use mobile touchscreen devices decisions

Thank you for taking the time to participate in this survey.

# Appendix D Message to invite participants to Delphi round two

**Dear xxx**

Thank you for accepting to take part in the second round of this data collection on mobile touchscreen devices (MTD's) end us of use decisions. There is no obligation to take part and you are free to withdraw at any time.

Back in July, the first round of this **Delphi study** helped narrow down 68 factors identified from the literature to 11 most significant factors. Now the second round involves the comparison of these factors against one another for each category: Reuse, Recycle and Discard. (Note: the responses for reuse and resell being extremely similar, the 2 categories were merged back together in "reuse"). The method is similar to the **Analytical Hierarchy Process (AHP),** however it requires less questions as factors have been ranked thanks to the first round.

After clicking on the link here below you will have 3 choices for each question and there should be less than 30 questions in total. You will be presented with **pairs of choices** and will have to decide which pair is the most significant or if they are equal (third choice). The survey is 100% online and can be completed in as many times as wished. The entire process requires around 15 minutes of your time. The deadline for completion is Friday 9th of October. A kind reminder will be sent within 2 weeks after receiving this message.

Once all responses are aggregated, preliminary results will be shared with participants who have accepted to take part in the second round - as previously done after the end of the first round.

Once again, the research team and myself would like to thank you for your time and expertise on the subject.

Best regards,

Xavier Pierron

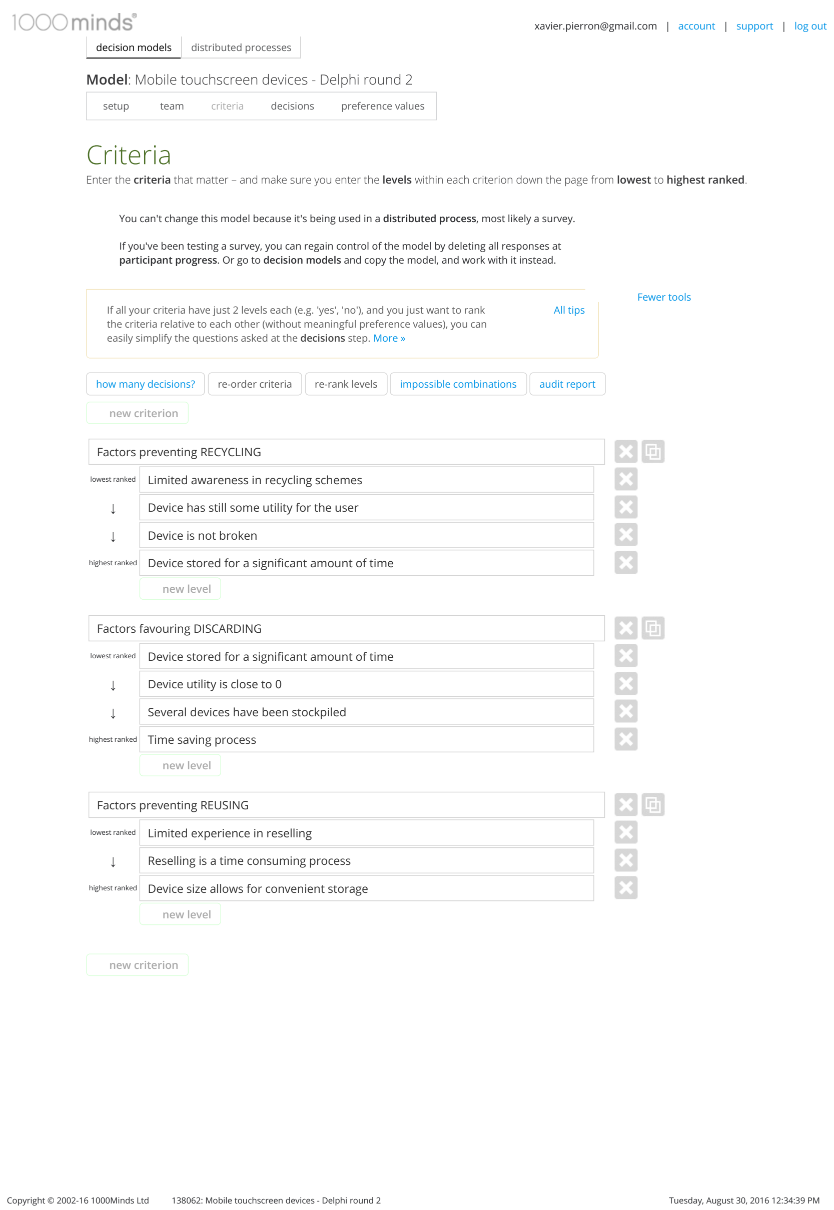
**Please click this link to start the survey:**

https://engine.1000minds.com/xDDM.aspx?r=wedv&q=w85hbkvs5cxytq7qf5ssu&s=1

This link is uniquely tied to your email address, so don't forward this message to other people. Please complete your survey by **Friday 16th of October.**

# Appendix E Delphi round two questionnaire structure and examples

The 1000minds method to present choices to respondents differs from SurveyMonkey or iSurvey. It combines a unique set of choices for each participant. Therefore, the entire questionnaire cannot be shown. Instead the architecture used to structure the choices and a couple of examples have been made available. After each choice is made, respondents are presented with another set of factors. Respondents had to make 20 decisions in total.



1000minds

xavier.pierron@gmail.com | account | support | log out

decision models | distributed processes

**Model**: Mobile touchscreen devices - Delphi round 2

setup | team | criteria | decisions | preference values

# Standalone consistency checker

Check the consistency of your decisions by re-answering the following questions, or use the **integrated consistency checker** (under **more tools**).

You can't change this model because it's being used in a **distributed process**, most likely a survey.

If you've been testing a survey, you can regain control of the model by deleting all responses at **participant progress**. Or go to **decision models** and copy the model, and work with it instead.

You either answered these questions explicitly or their answers were logically implied by your answers to the questions you were asked. All tips

Fewer tools

integrated consistency checker

**Which of these 2 (hypothetical) alternatives do you prefer?**
(all else being equal)

| | | |
|---|---|---|
| Factors favouring DISCARDING<br>**Device stored for a significant amount of time**<br>Factors preventing REUSING<br>**Device size allows for convenient storage** | | Factors favouring DISCARDING<br>**Device utility is close to 0**<br>Factors preventing REUSING<br>**Limited experience in reselling** |
| this one | OR | this one |

they are equal

skip this question for now »

 138062: Mobile touchscreen devices - Delphi round 2 Tuesday, August 30, 2016 12:36:10 PM

# Appendix F Social survey ethics approval message from UoS

-------- Original message --------

From: ERGO

Date:02/23/2016 08:47 (GMT+00:00)

To: xp1v12@soton.ac.uk

Subject: Your Ethics Submission (Ethics ID:18705) has been reviewed and approved

Submission Number: 18705

Submission Name: Evaluating students' mobile / smart phones usage and end-of-use decisions

This is email is to let you know your submission was approved by the Ethics Committee.

Comments

None

Click here to view your submission

------------------

ERGO : Ethics and Research Governance Online

http://www.ergo.soton.ac.uk

# Appendix G Social survey ethics approval message from CU

Project [P39761]

Students mobile devices usage and end of use decisions

Project Details | Comments (9) | Downloads | Approval Steps

Bristol Online Survey will be used. The pdf submitted is to illustrate the questions that will be used. Thank you.

Xavier Pierron - 15 Jan 2016 03:01 PM

**Evaluation of the ethics of the proposal:**
medium risk research involving on-line (BOS) quantitative survey of CU students concerning their use of smart phones and their behaviour regarding recycling of same. Financial incentive (draw for prize) provided which should not affect data quality or compromise participant rights. some minor clarification/tweaking issues required for authorisation (see below).

Philip Dunham - 19 Jan 2016 10:03 AM

**Evaluation of the participant information sheet and consent form:**
appropriate documents submitted. Questionnaire will be delivered through BoS. some minor changes needed.

Philip Dunham - 19 Jan 2016 10:03 AM

**Conditions or reasons that support your recommendation:**
Clear application. some minor changes needed prior to authorisation. please make these and then re-submit...
1) clarify in application how you propose to approach students to take part - what is your sample frame/strategy?
2) clarify in PIL that you are a CU staff member as well as PGR student at Southampton.
3) complete PIL section on how participants could make a complaint and to whom. Provide details of the Assoc Dean Research or your line manager here.
4) Ensure that BOS questionnaire contains all the required PIL information at the start, and include a tick box [necessary for them to proceed] to record their [informed] consent to continue with/particpiate in the survey.

Philip Dunham - 19 Jan 2016 10:03 AM

Thank you Ethics Committee for your comments. Sampling information has been updated in question 4. PIL has been updated and relevant segments have been highlighted. Questionnaire now includes the recording of participants informed consent.

Xavier Pierron - 21 Jan 2016 09:32 AM

Thank you Ethics Committee for your comments. PIL has been updated and relevant sections highlighted. Questionnaire now includes the step for participants to record their informed consent and sampling information has been added in question 4.

Xavier Pierron - 21 Jan 2016 09:35 AM

**Conditions or reasons that support your recommendation:**
Sampling method now clarified. Explicit affirmation of consent now recorded on the BOS questionnaire.

1) Amendments to PIL still required
2) Not all the information on the PIL is included in the opening section of the questionnaire. It is essential (for obtaining INFORMED consent) that this info is seen by the participants. Either paste the main points of the PIL into the on-line questionnaire (this could be in a small font info box at start), or provide assurance/explain that the participants will see the PIL via other means.

Philip Dunham - 21 Jan 2016 11:58 AM

PIL updated according to comments made by ethics committee and PIL key information as well as informed consent approval have been inserted at the beginning of the questionnaire. Both updated documents have been uploaded.
Thank you.

Xavier Pierron - 22 Jan 2016 02:46 PM

**Conditions or reasons that support your recommendation:**
Best wishes for the research.

Philip Dunham - 25 Jan 2016 01:10 PM

9 Comments

# Appendix H Message sent to social survey prospective participants

“The Centre of Environmental Sciences from the University of Southampton is conducting research on students mobile / smart phone usage and end of use decisions. The survey lasts approximately 10 minutes and participants completing the online form can enter a prize draw in Amazon vouchers: first prize £200, second £150 and third £100. The prize draw will occur on Wednesday 30th of March 2016 and winners will be contacted via email within a week.

The study objective is to assess mobile / smart phones usage and disposal patterns and identify non-monetary incentives that could trigger recycling behaviours. Additionally, there are questions related to the previous devices’ characteristics and decisions associated to their end-of-use. More specific information about the survey is available on the introduction page. https://www.surveymonkey.co.uk/r/KVPVP2C

If you have any questions you can contact Xavier Pierron xp1v12@soton.ac.uk

Thank you in advance for your time and good luck!”

# Appendix I Social survey questionnaire and participant information sheet

## Evaluating students' mobile / smart phones usage and end-of-use decisions

1. Participant Information Sheet

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to register your informed consent by clicking on the next button at the end of the page.

My name is Xavier Pierron and I am a PG researcher at the Centre of Environmental Sciences at the University of Southampton.

What is the research about?
The study aims to evaluate students' mobile / smart phones usage and end-of-use decisions. The study objective is to assess **mobile / smart phones usage and disposal patterns** and identify non-monetary incentives that could trigger recycling behaviours. In the questionnaire mobile / smart phones are sometimes referred to handsets or mobile devices.

Why have I been chosen?
As a university student you are very likely to own and use a mobile or smart phone. Therefore you have been chosen as a potential participant.

What will happen to me if I take part?
The **survey lasts approximately 10 minutes** with questions related to your current device characteristics, general usage pattern, such as how much time per day is spent using the device. There are also questions about potential incentives you believe could trigger a recycling behaviour. Additionally there are questions related to the previous devices' characteristics and the decision associated to their end-of-use. At the end of the questionnaire demographic information will be asked such as age, university status (home / EU or overseas student) or current degree enrolled. This information will be used to assess the sample representativity against the UK wider student population. By completing the survey you also have the opportunity to take part in a prize draw in Amazon vouchers among all survey respondents; **first prize = £200, second = £150 and third = £100**. At the end of the survey participants will be invited to enter their email should they wish to participate in the prize draw.

Are there any benefits in my taking part?
Yes, participants enter a prize draw as indicated here above. The intention is to incentive respondents to take part in this questionnaire. We aim at collecting a maximum of possible responses to build a sample representative of the UK higher education population.

Are there any risks involved?
There are no risks involved as the survey is desk-based and the entire data collection is processed online.

Will my participation be confidential?
All data collected during this study will be confidential, and handled in compliance with the Data Protection Act and University policy. Data will be stored on a password protected computer, and will only be used for the purposes of this study. Only those involved with the study will be able to access information. Whilst complete anonymity cannot be promised, all files containing any personal information will be made anonymous to prevent identification of participants. Confidentiality will be maintained as the data will remain anonymous in any publication of results.

What happens if I change my mind?
You have the right to withdraw at any time without your legal rights being affected.

What happens if something goes wrong?
In the unlikely case of concern or complaint, you should contact the Research Governance Manager (02380 595058, rgoinfo@soton.ac.uk) is happy to be the named party.

Where can I get more information?
If you have any questions or concerns regarding completion of the questionnaire, please contact: Xavier Pierron at xp1v12@soton.ac.uk.

By clicking on the "next" button here below, participants are recoding their informed consent to take part in this survey.

## Evaluating students' mobile / smart phones usage and end-of-use decisions

### 2. Current mobile or smart phone usage

If you use more than one device, please provide responses related to the one you use the most.

Mobile phone users might find some questions less relevant (compared to smart phone users). Please attempt to answer them to the best of your knowledge.

*** 1. Mobile device details**

Please enter your device brand (ex: Samsung) [ ]

Please enter your device make (ex: Galaxy 5) [ ]

*** 2. Please enter acquisition date (enter "01" for the day).**

| | DD | | MM | | YYYY |
|---|---|---|---|---|---|
| Date | [ ] | / | [ ] | / | [ ] |

*** 3. Acquisition state**

[ ]

*** 4. Contract type**

- ◯ Pay as you go
- ◯ 12 months contract
- ◯ 18 months contract
- ◯ 24 months contract
- ◯ Other (please specify)

[ ]

*** 5. Monthly average spent on pay as you go or contracts**

[ ]

**6. Morning average screen time (from waking up to lunch) (screen time = time spent using the device)**

[ ]

**7. Afternoon average screen time (lunch included until dinner)**

**8. Evening average screen time, dinner included until sleep**

*** 9. Approximately how much data is stored in your smart phone**

**10. Estimate how useful is your current mobile phone to you.**

| | 0 (absolutely not useful) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 (extremely useful) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Usefulness to you | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

*** 11. Estimate your phone current market value (in GBP and alphanumerical only).**

*** 12. Within approximately how many months would you replace your device?**

*** 13. Estimate your device market value when it will be replaced (in GBP and alphanumerical only).**

*** 14. Retrieve your device current market value and enter the data in the box here below https://www.compareandrecycle.co.uk/mobile-phones**

*** 15. Indicate in one word the emotion felt when comparing your device estimated value and its current market value.**

**16. Knowing the difference between the market value and your estimate, would you replace sooner your device?**

## Evaluating students' mobile / smart phones usage and end-of-use decisions

### 3. Mobile or smart phone end of use decisions

The following questions relate to the device(s) you are not using any more.

* **17. *How many devices are stored in your home? If none, please go to question 22.***

**18. What was the initial intention when storing the device(s)?**

**19. Has that event occurred?**

Other (please specify)

**20. If we could design a fun incentive (non-monetary) that would nudge you to taking the device(s) back to an on-campus collection point, what would it be?**

**21. Rank the most important factors leading to store your device(s).**

| | Size allows for convenient storage | Device may still have some usefulness | Reselling is a time consuming process | Limited experience in recycling or reselling | Potential data confidentiality issues | Device was not broken |
|---|---|---|---|---|---|---|
| 0 meaning insignificant factor in your decision and 4 being extremely important) | | | | | | |

Other (please specify)

5

* 22. *Have you ever given (to a friend or family) a mobile device? If no, please go to question 27.*

23. **Device initial acquisition state.**

**24. Was it a pay as you go or a contract subscription?**

- Pay as you go
- Contract
- Other (please specify)

**25. How long had it been unused for before being given away?**

**26. Estimate how useful was the device to you at the time it was given away.**

| | 0 (absolutely not useful) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 (extremely useful) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Device usefulness to you | | | | | | | | | | | |

* 27. *Have you ever resold a mobile device? If no, please go to question 32.*

**28. Device initial acquisition state**

**29. Was it a pay as you go or a contract subscription?**

- Pay as you go
- Contract
- Other (please specify)

**30. How long had it been unused for before being resold?**

6

**31. Estimate how useful was the device to you at the time it was resold.**

| | 0 (absolutely not useful) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 (extremely useful) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Device usefulness to you | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

* **32. *Have you ever recycled a mobile device? If no, please go to question 36.***

**33. Device initial acquisition state**

**34. Was it a pay as you go or a contract subscription?**

◯ Pay as you go

◯ Contract

◯ Other (please specify)

**35. How long had it been unused for before being recycled?**

**36. Estimate how useful was the device when it was recycled.**

| | 0 (absolutely not useful) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 (extremely useful) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Device usefulness to you | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

* **37. *Have you ever discarded a mobile device in the general refuse? If no, please go to question 42.***

**38. Device initial acquisition state**

**39. Was it a pay as you go or a contract subscription?**

- ◯ Pay as you go
- ◯ Contract
- ◯ Other (please specify)

**40. How long had it been unused before being discarded?**

**41. Estimate how useful was the device when it was discarded.**

| | 0 (absolutely not useful) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 (extremely useful) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Usefulness to you | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ | ◯ |

## Evaluating students' mobile / smart phones usage and end-of-use decisions

4. Please input your demographics to finalise the survey, thank you.

*** 42. Are you male or female?**

- ◯ Male
- ◯ Female

*** 43. Are you an overseas or home / EU student?**

- ◯ Home / EU
- ◯ Overseas

**44. What is your age?**

- ◯ 15-19
- ◯ 20-24
- ◯ 25-29
- ◯ 30-34
- ◯ 35-39
- ◯ 40-44
- ◯ 45 or older

# Appendix J Prize draw messages to winners

**Sent**

a for Amazon - E-mail Amazon.co.uk Gift Voucher

Message:
Hello, If you recall you accepted to participate in the mobile phone survey prize draw. And ...
you have won the third prize! Congratulations! Hope you will enjoy it and please
acknowledge reception of this message by sending an email back to xp1v12@soton.ac.uk
Thank you :)

| Amount | Sent to | Status |
|---|---|---|
| £100.00 | lzw1g13@soton.ac.uk | Sent |

Resend Gift Voucher

Hide Order

ORDER PLACED
30 March 2016

TOTAL
£150.00

ORDER # 206-8987682-8589135
Order Details | Invoice

**Sent**

a for Amazon - E-mail Amazon.co.uk Gift Voucher

Message:
Hello, If you recall you accepted to participate in the mobile phone survey prize draw. And ...
you have won the second prize! Congratulations! Hope you will enjoy it and please
acknowledge reception of this message by sending an email back to xp1v12@soton.ac.uk
Thank you :)

| Amount | Sent to | Status |
|---|---|---|
| £150.00 | jakeburnett94@yahoo.co.uk | Redeemed |

Hide Order

ORDER PLACED
30 March 2016

TOTAL
£200.00

ORDER # 206-5297077-4276342
Order Details | Invoice

**Sent**

a for Amazon - E-mail Amazon.co.uk Gift Voucher

Message:
Hello, If you recall you accepted to participate in the mobile phone survey prize draw. And ...
you have won the first prize! Congratulations! Hope you will enjoy it and please
acknowledge reception of this message by sending an email back to xp1v12@soton.ac.uk
Thank you

| Amount | Sent to | Status |
|---|---|---|
| £200.00 | emm1g13@soton.ac.uk | Redeemed |

Hide Order

# Appendix K MWU and KW tests outputs

**a. Grouping Variable: Gender / MWU**

**Test Statistics[a]**

| | months ago | Phone current value | Phone future value | Phone market value | delta | Emotion felt coded |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 30419.500 | 30772.000 | 29714.500 | 26280.500 | 24133.000 | 23946.000 |
| Wilcoxon W | 56754.500 | 68722.000 | 66842.500 | 58411.500 | 56264.000 | 46524.000 |
| Z | -.449 | -.440 | -.725 | -.544 | -1.614 | -1.654 |
| Asymp. Sig. (2-tailed) | .653 | .660 | .469 | .586 | .106 | .098 |

**Test Statistics[a]**

| | Replacement time frame | Utility | Data stored | screen time total | Devices quantity stored | convenient storage |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 28619.500 | 27932.000 | 27975.000 | 26065.000 | 30734.000 | 31704.500 |
| Wilcoxon W | 55880.500 | 65882.000 | 54310.000 | 62921.000 | 68684.000 | 69654.500 |
| Z | -2.255 | -2.646 | -2.129 | -3.176 | -.902 | -.312 |
| Asymp. Sig. (2-tailed) | .024 | .008 | .033 | .001 | .367 | .755 |

**Test Statistics[a]**

| | utility left | reselling time consuming | Limited experience in recycling or reselling | Potential data confidentiality issues | Given utility | Resold utility |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 30959.500 | 31799.500 | 30860.000 | 31858.500 | 7153.000 | 1195.500 |
| Wilcoxon W | 58454.500 | 59294.500 | 68810.000 | 59353.500 | 15154.000 | 3086.500 |
| Z | -.773 | -.244 | -.859 | -.209 | -.950 | -1.138 |
| Asymp. Sig. (2-tailed) | .440 | .807 | .390 | .834 | .342 | .255 |

**Test Statistics[a]**

| | Recycled utility | Discarded utility | Given - how long before decision | Resold - how long before decision | Recycled - how long before decision | Discarded - how long before decision |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 1477.000 | 550.000 | 5039.500 | 1055.000 | 699.000 | 356.000 |
| Wilcoxon W | 3430.000 | 1253.000 | 10604.500 | 2766.000 | 1560.000 | 986.000 |
| Z | -.612 | -1.133 | -.527 | -.612 | -.410 | -2.158 |
| Asymp. Sig. (2-tailed) | .541 | .257 | .598 | .540 | .682 | .031 |

b. Grouping Variable: Origin / MWU

**Test Statistics[a]**

| | months ago | Phone current value | Phone future value | Phone market value | delta | Emotion felt coded |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 22505.000 | 18792.000 | 17278.000 | 17529.500 | 17565.500 | 18239.000 |
| Wilcoxon W | 101111.000 | 98992.000 | 96679.000 | 85794.500 | 85093.500 | 85767.000 |
| Z | -.331 | -2.998 | -3.651 | -1.902 | -1.381 | -.268 |
| Asymp. Sig. (2-tailed) | .741 | .003 | .000 | .057 | .167 | .789 |

**Test Statistics[a]**

| | Replacement time frame | Utility | Data stored | screen time total | Devices quantity stored | convenient storage |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 21469.500 | 20668.000 | 22246.500 | 21982.000 | 19378.500 | 23348.000 |
| Wilcoxon W | 28490.500 | 27689.000 | 29032.500 | 100985.000 | 26399.500 | 30369.000 |
| Z | -1.663 | -2.191 | -.541 | -.609 | -3.136 | -.284 |
| Asymp. Sig. (2-tailed) | .096 | .028 | .589 | .543 | .002 | .777 |

**Test Statistics[a]**

| | utility left | reselling time consuming | Limited experience in recycling or reselling | Potential data confidentiality issues | Given utility | Resold utility |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 18888.000 | 22214.000 | 23590.500 | 23246.500 | 5187.500 | 1055.000 |
| Wilcoxon W | 25909.000 | 29235.000 | 104593.500 | 104249.500 | 23332.500 | 4058.000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Z | -3.542 | -1.129 | -.096 | -.361 | -.869 | -.438 |
| Asymp. Sig. (2-tailed) | .000 | .259 | .923 | .718 | .385 | .661 |

**Test Statistics[a]**

| | Recycled utility | Discarded utility | Given - how long before decision | Resold - how long before decision | Recycled - how long before decision | Discarded - how long before decision |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 1214.000 | 324.000 | 3566.500 | 690.000 | 265.500 | 369.500 |
| Wilcoxon W | 4869.000 | 1702.000 | 15194.500 | 3391.000 | 2543.500 | 579.500 |
| Z | -.123 | -2.787 | -1.519 | -1.982 | -1.522 | -1.207 |
| Asymp. Sig. (2-tailed) | .902 | .005 | .129 | .047 | .128 | .228 |

**c. Grouping Variable: UG PG students / MWU**

**Test Statistics[a]**

| | months ago | Phone current value | Phone future value | Phone market value | delta | Emotion felt coded |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 26466.000 | 26501.000 | 25604.500 | 23109.500 | 21394.000 | 21551.000 |
| Wilcoxon W | 37344.000 | 37527.000 | 36482.500 | 32562.500 | 30710.000 | 77496.000 |
| Z | -.239 | -.431 | -.717 | -.133 | -1.083 | -.686 |
| Asymp. Sig. (2-tailed) | .811 | .667 | .474 | .895 | .279 | .493 |

**Test Statistics[a]**

| | Replacement time frame | Utility | Data stored | screen time total | Devices quantity stored | convenient storage |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 26210.500 | 26974.500 | 25197.000 | 23387.000 | 27612.500 | 27415.500 |
| Wilcoxon W | 37385.500 | 95980.500 | 35782.000 | 34265.000 | 96618.500 | 38590.500 |
| Z | -.953 | -.443 | -.982 | -2.284 | -.018 | -.159 |
| Asymp. Sig. (2-tailed) | .340 | .658 | .326 | .022 | .986 | .874 |

**Test Statistics[a]**

| | utility left | reselling time consuming | Limited experience in recycling or reselling | Potential data confidentiality issues | Given utility | Resold utility |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 26328.000 | 26606.000 | 26792.500 | 27277.000 | 4873.000 | 846.500 |
| Wilcoxon W | 37503.000 | 95612.000 | 95798.500 | 96283.000 | 20449.000 | 3927.500 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Z | -.891 | -.719 | -.593 | -.257 | -3.017 | -1.769 |
| Asymp. Sig. (2-tailed) | .373 | .472 | .553 | .797 | .003 | .077 |

**Test Statistics[a]**

| | Recycled utility | Discarded utility | Given - how long before decision | Resold - how long before decision | Recycled - how long before decision | Discarded - how long before decision |
|---|---|---|---|---|---|---|
| Mann-Whitney U | 1135.000 | 553.500 | 4296.000 | 798.000 | 610.000 | 432.500 |
| Wilcoxon W | 4456.000 | 1778.500 | 14736.000 | 1176.000 | 863.000 | 642.500 |
| Z | -1.283 | -.417 | -.455 | -1.395 | -.069 | -.262 |
| Asymp. Sig. (2-tailed) | .199 | .676 | .649 | .163 | .945 | .793 |

**d. Grouping Variable: Utility 3 levels / KW**

**Test Statistics[a,b]**

| | months ago | Phone current value | Phone future value | Phone market value | delta | Emotion felt coded | Replacement time frame |
|---|---|---|---|---|---|---|---|
| Chi-Square | .589 | 17.214 | 16.258 | 16.518 | 3.998 | 6.042 | 3.952 |
| df | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .745 | .000 | .000 | .000 | .136 | .049 | .139 |

**Test Statistics[a,b]**

| | Utility | Data stored | Monthly spent | screen time total | Devices quantity stored | convenient storage | utility left |
|---|---|---|---|---|---|---|---|
| Chi-Square | 335.110 | 6.734 | 5.961 | 4.768 | 2.694 | .250 | 1.304 |
| df | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .000 | .034 | .051 | .092 | .260 | .882 | .521 |

**Test Statistics[a,b]**

| | reselling time consuming | Limited experience in recycling or reselling | Potential data confidentiality issues | Given utility | Resold utility | Recycled utility |
|---|---|---|---|---|---|---|
| Chi-Square | .803 | .811 | .360 | 4.941 | 1.760 | 2.973 |
| df | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .669 | .667 | .835 | .085 | .415 | .226 |

**Test Statistics[a,b]**

| | Discarded utility | Given - how long before decision | Resold - how long before decision | Recycled - how long before decision | Discarded - how long before decision |
|---|---|---|---|---|---|
| Chi-Square | 2.843 | 2.944 | 1.707 | .490 | .223 |
| df | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .241 | .229 | .426 | .783 | .894 |

**e. Grouping Variable: Emotion felt coded / KW**

**Test Statistics[a,b]**

| | months ago | Phone current value | Phone future value | Phone market value | delta | Replacement time frame | Utility |
|---|---|---|---|---|---|---|---|
| Chi-Square | 4.632 | 30.286 | 16.843 | .625 | 118.532 | 1.727 | 4.454 |
| df | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .099 | .000 | .000 | .731 | .000 | .422 | .108 |

**Test Statistics[a,b]**

| | Data stored | Monthly spent | screen time total | Devices quantity stored | convenient storage | utility left | reselling time consuming |
|---|---|---|---|---|---|---|---|
| Chi-Square | .674 | 4.515 | 6.386 | .013 | 2.631 | .734 | 1.608 |
| df | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .714 | .105 | .041 | .994 | .268 | .693 | .448 |

**Test Statistics[a,b]**

| | Limited experience in recycling or reselling | Potential data confidentiality issues | Given utility | Resold utility | Recycled utility | Discarded utility |
|---|---|---|---|---|---|---|
| Chi-Square | 1.297 | 2.010 | 1.218 | .772 | 3.555 | .544 |
| df | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .523 | .366 | .544 | .680 | .169 | .762 |

**Test Statistics[a,b]**

| | Given - how long before decision | Resold - how long before decision | Recycled - how long before decision | Discarded - how long before decision |
|---|---|---|---|---|
| Chi-Square | 2.710 | 1.099 | 1.760 | .153 |
| df | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .258 | .577 | .415 | .927 |

**f. Grouping Variable: screen time 3 levels / KW**

**Test Statistics[a,b]**

| | months ago | Phone current value | Phone future value | Phone market value | delta | Replacement time frame | Utility |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Chi-Square | 3.017 | 36.156 | 43.003 | 32.048 | 13.940 | 1.357 | 7.502 |
| df | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .221 | .000 | .000 | .000 | .001 | .507 | .023 |

**Test Statistics[a,b]**

| | Data stored | Monthly spent | screen time total | Devices quantity stored | convenient storage | utility left | reselling time consuming |
|---|---|---|---|---|---|---|---|
| Chi-Square | 19.983 | 31.098 | 417.533 | 18.891 | 10.584 | 6.427 | 11.608 |
| df | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .000 | .000 | .000 | .000 | .005 | .040 | .003 |

**Test Statistics[a,b]**

| | Limited experience in recycling or reselling | Potential data confidentiality issues | Given utility | Resold utility | Recycled utility | Discarded utility |
|---|---|---|---|---|---|---|
| Chi-Square | 7.687 | 16.939 | .292 | 2.509 | 1.760 | 1.434 |
| df | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .021 | .000 | .864 | .285 | .415 | .488 |

**Test Statistics[a,b]**

| | Given - how long before decision | Resold - how long before decision | Recycled - how long before decision | Discarded - how long before decision | Emotion felt coded |
|---|---|---|---|---|---|
| Chi-Square | 1.925 | 11.069 | 4.480 | .428 | 6.535 |
| df | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .382 | .004 | .106 | .807 | .038 |

**g. Grouping Variable: Age 3 levels**

**Test Statistics[a,b]**

| | months ago | Phone current value | Phone future value | Phone market value | delta | Replacement time frame | Utility |
|---|---|---|---|---|---|---|---|
| Chi-Square | .027 | 7.146 | 9.691 | 1.309 | 7.825 | .262 | .502 |
| df | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .987 | .028 | .008 | .520 | .020 | .877 | .778 |

**Test Statistics[a,b]**

| | Data stored | Monthly spent | screen time total | Devices quantity stored | convenient storage | utility left | reselling time consuming |
|---|---|---|---|---|---|---|---|
| Chi-Square | 8.113 | .904 | 12.154 | .051 | 5.099 | 1.022 | 1.558 |
| df | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .017 | .636 | .002 | .975 | .078 | .600 | .459 |

**Test Statistics[a,b]**

| | Limited experience in recycling or reselling | Potential data confidentiality issues | Given utility | Resold utility | Recycled utility | Discarded utility |
|---|---|---|---|---|---|---|
| Chi-Square | 5.967 | 4.679 | .225 | 3.860 | 4.645 | .576 |
| df | 2 | 2 | 2 | 2 | 2 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Asymp. Sig. | .051 | .096 | .894 | .145 | .098 | .750 |

**Test Statistics[a,b]**

| | Given - how long before decision | Resold - how long before decision | Recycled - how long before decision | Discarded - how long before decision | Emotion felt coded |
|---|---|---|---|---|---|
| Chi-Square | 11.475 | 3.125 | 1.146 | 1.315 | 2.718 |
| df | 2 | 2 | 2 | 2 | 2 |
| Asymp. Sig. | .003 | .210 | .564 | .518 | .257 |

# Appendix L Screen time and dependent variables descriptive statistics

### A. Report

| screen time 3 levels | | Phone current value | Phone future value | Phone market value | delta | Utility | Data stored |
|---|---|---|---|---|---|---|---|
| Low | Mean | 172.820 | 111.85 | 108.6155 | 68.8174 | 8.03 | 2.07 |
| | N | 206 | 205 | 189 | 188 | 207 | 201 |
| | Std. Deviation | 145.4771 | 353.590 | 113.04746 | 99.08672 | 1.915 | .977 |
| Med | Mean | 262.257 | 149.40 | 152.1763 | 117.0441 | 8.24 | 2.42 |
| | N | 253 | 248 | 232 | 229 | 256 | 255 |
| | Std. Deviation | 356.6471 | 136.945 | 120.06074 | 339.56873 | 2.207 | 1.068 |
| High | Mean | 306.229 | 188.24 | 187.9771 | 122.0872 | 8.31 | 2.75 |
| | N | 48 | 49 | 48 | 47 | 49 | 48 |
| | Std. Deviation | 190.3501 | 139.396 | 116.48259 | 114.15348 | 2.257 | 1.194 |
| Total | Mean | 230.081 | 137.85 | 138.2860 | 98.0148 | 8.16 | 2.31 |
| | N | 507 | 502 | 469 | 464 | 512 | 504 |
| | Std. Deviation | 278.7283 | 250.215 | 119.64808 | 250.25185 | 2.098 | 1.066 |

### Report

| screen time 3 levels | | Monthly spent | Devices quantity stored | convenient storage | utility left | reselling time consuming | Limited experience in recycling or reselling |
|---|---|---|---|---|---|---|---|
| Low | Mean | 1.82 | 1.08 | 1.87 | 2.82 | 1.97 | 1.94 |
| | N | 192 | 207 | 207 | 207 | 207 | 207 |
| | Std. Deviation | .960 | 1.238 | 1.299 | 1.791 | 1.333 | 1.333 |
| Med | Mean | 2.21 | 1.66 | 2.27 | 3.25 | 2.42 | 2.28 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | N | 228 | 256 | 256 | 256 | 256 | 256 |
| | Std. Deviation | 1.167 | 1.507 | 1.462 | 1.701 | 1.474 | 1.446 |
| High | Mean | 2.98 | 1.76 | 2.24 | 3.10 | 2.18 | 2.16 |
| | N | 43 | 49 | 49 | 49 | 49 | 49 |
| | Std. Deviation | 1.371 | 1.535 | 1.437 | 1.771 | 1.349 | 1.359 |
| Total | Mean | 2.12 | 1.44 | 2.11 | 3.06 | 2.21 | 2.13 |
| | N | 463 | 512 | 512 | 512 | 512 | 512 |
| | Std. Deviation | 1.153 | 1.435 | 1.407 | 1.753 | 1.420 | 1.400 |

## Report

| screen time 3 levels | | Potential data confidentiality issues | Resold - how long before decision | Emotion felt coded |
|---|---|---|---|---|
| Low | Mean | 1.816 | 2.07 | 1.75 |
| | N | 207 | 30 | 186 |
| | Std. Deviation | 1.3054 | 1.437 | .723 |
| Med | Mean | 2.324 | 1.73 | 1.59 |
| | N | 256 | 56 | 227 |
| | Std. Deviation | 1.4952 | 1.243 | .737 |
| High | Mean | 2.327 | 2.91 | 1.62 |
| | N | 49 | 11 | 47 |
| | Std. Deviation | 1.4915 | 1.221 | .739 |
| Total | Mean | 2.119 | 1.97 | 1.66 |
| | N | 512 | 97 | 460 |

| | | | |
|---|---|---|---|
| Std. Deviation | 1.4401 | 1.342 | .734 |

# Appendix M Delphi study coding

| Categories | Factors | Coding | CVR Score |
|---|---|---|---|
| Recycle | Users tend to recycle their device after being stored for a significant amount of time. | time | 0.72 |
| | Users tend not to recycle unbroken (still working) devices. | utility | 0.62 |
| | If the device has still some usefulness for the user, it will not be recycled. | utility | 0.62 |
| | Users have a limited awareness of existing recycling opportunities for this type of device. | awareness | 0.46 |
| | The device size being limited, storing it instead of recycling it is not an issue. | size | 0.44 |
| | The device usefulness is higher as a backup or spare, better not to recycle it and store it at home. | utility | 0.35 |
| | Users have a limited experience in electronic waste recycling, thus tend not to recycle this type of device. | experience | 0.32 |
| | Recycling this type of device is costly. | cost | -0.87 |
| | Users have a limited experience in recycling household waste, thus tend not to recycle this type of device. | experience | -0.49 |
| | Recycling this type of device is time-consuming. | time | -0.39 |
| | Recycling this type of device is not convenient. | convenience | -0.34 |
| | Users lack of ethical values, thus they don't recycle this type of device. | values | -0.34 |
| | There could be a more convenient opportunity in the future to recycle this type of device; better to store it at home in the meantime. | utility | -0.31 |
| | The recycling information gathering process is complex, better not to recycle the device and store it at home. | information | -0.30 |
| | Users lack of altruistic values, thus they don't recycle this type of device. | values | -0.29 |
| Discard | Discarding this type of device in the general refuse is time-saving. | convenience / time | 0.64 |
| | Too many devices have been stored at home, now it is time to get rid of them. | quantity | 0.61 |
| | The closer the device usefulness is to 0, the more likely it will be discarded. | utility | 0.56 |

| | | | |
|---|---|---|---|
| | Users tend to discard their device after being stored for a significant amount of time. | time | 0.55 |
| | Discarding this type of device in the general refuse is convenient. | convenience | 0.55 |
| | Device has not been used as backup or spare as initially hoped. Its usefulness is close to nothing and should be discarded. | utility | 0.45 |
| | The device has been stored for a large amount of time and now needs to be discarded. | time | 0.35 |
| | Users have limited experience in electronic waste recycling, they simply tend to discard this type of device. | experience | 0.34 |
| | Obsolete devices tend to be more recycled than discarded. | time | -0.37 |
| **Resell** | The device size being limited, storing it instead of reselling it is not an issue. | size | 0.51 |
| | The device size being limited, storing it for a potential later use is more useful than reselling it. | utility | 0.31 |
| | Reselling this type of device is time-consuming. | experience / time | 0.29 |
| | Reselling this type of device is costly. | cost | -0.88 |
| | Users tend to resell their device immediately after acquiring a new one. | time | -0.56 |
| | There could be a more convenient opportunity in the future to resell this type of device; better to store it at home. | utility | -0.48 |
| **Give away** | The device size being limited, storing it instead of giving it is not an issue. | size | 0.52 |
| | Users tend to give their device away immediately after acquiring a new one. | time | -0.39 |

# Appendix N Published paper

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## Using choice architecture to exploit a university Distinct Urban Mine

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A B S T R A C T

There are widespread concerns regarding the potential future scarcity of ferrous and non-ferrous materials. However, there are already potentially rich reserves of secondary materials via high ownership of Electrical and Electronic Equipment (EEE) in economically-developed nations. Young people are particularly high consumers of EEE, thus university students and campuses may present an opportunity to harness this potential. University Distinct Urban Mines (DUM) may be used to exemplify how potential reserves of secondary metals may be exploited, and could contribute to the transition from a linear to a circular economy. This study aimed to evaluate small household appliances (SHA) DUM from a UK university, with the objectives to identify and quantify student households' SHA ownership, WEEE recycling, stockpiling and discarding habits amongst student households, assess and evaluate the monetary potential of SHA DUM at UK level, and propose methods to exploit DUM for universities in the UK.

To this purpose, a quantitative survey was undertaken to measure students' ownership and discarding behaviour with respect to SHA. The amounts of ferrous and non-ferrous materials were then estimated and converted to monetary values from secondary materials market data to appraise the SHA DUM overall value. Thirty-five per cent of SHA are discarded in the general refuse. Broken personal care appliances (PCA) tend to be discarded due to hygiene and small size factors. When in working order, SHA tend to be equally reused, recycled or stockpiled. We conclude that a total of 189 tonnes of ferrous and non-ferrous materials were available via discarding or being stockpiled at the University of Southampton. Extrapolated to UK higher education level, discarded and stockpiled SHA represent a potential worth ~USD 11 million. To initiate DUM exploitation within Higher Education campuses, we suggest improving users' choice architecture by providing collection methods specific to broken SHA.



**Contents**



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