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Disposal of obsolete mobile phones: A review on replacement, disposal methods, in-use lifespan, reuse and recycling

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Abstract

Usage/consumption of mobile phones has increased rapidly around the world. As of April 2021, there were 5.27 billion mobile phone users. Meanwhile, the generation of obsolete mobile phones/mobile phone wastes is also increased mainly due to the replacement of mobile phones. The in-use lifespan of mobile phones is correspondingly getting decreased. The inappropriate disposal of obsolete mobile phones leads to adverse consequences on the environment, human health and on metal recovery. This review article provides an insight on findings from various articles on disposal of obsolete mobile phones by users/consumers. The various aspects, such as reasons for replacement, disposal methods adopted by users/consumers, impact due to the adoption of improper disposal methods such as handing them over to the informal recycling sector and storage/hibernation after its in-use lifespan, were covered. Along with this, the study even focuses on reduce, reuse and recycle (3Rs) of sustainability. Reduce means reduction of mobile phone replacement frequency. Storage of mobile phones post-in-use lifespan is the most opted disposal method, and it is one of the significant barriers to reuse, recycling and metal recovery. When it comes to recycling, the research undertaken on the recycling of obsolete mobile phones is not as in-depth when compared to the research done on recycling of e-waste in general. This article identifies future directions for sustainable end-of-life management of obsolete mobile phones.

Keywords

E-waste, obsolete mobile phones, mobile phone waste, reuse, recycling, hibernation

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Introduction

As a result of the innovation-based drastic development of the electronic industry, usage and consumption of different types of electronic devices, especially mobile phones have increased very much. This has also led to the rise in the generation of electronic waste (e-waste) around the world, and e-waste has become one of the fastest-growing waste streams in the world (Dwivedy and Mittal, 2012; Vaish et al., 2020). The electrical and electronic equipment (EEE) that have reached their end-of-life either due to functional failures or ceasing to be of any value to its owners is considered as e-waste (Widmer et al., 2005). In other words, e-waste is a term that is used to refer to those electronic devices that have either been discarded or retired from the use by the user (Dwivedy and Mittal, 2012). Hence, obsolete mobile phones are also considered as mobile phone wastes.

The rapid innovation, technical changes and new product proliferation has turned the mobile phone industry into an extremely dynamic one (Cecere et al., 2015). As of April 2021, there were nearly 5.27 billion mobile phone users in the world (Kemp, 2021). The frequent launch of new mobile phone models by various mobile phone companies induces consumers' willingness to purchase a more advanced device, and this is one of the main reasons due to which consumers replace their mobile phones even though their current ones being functional (Araújo et al., 2012; Islam et al., 2020; Li et al., 2012, 2015; Martinho et al., 2017; Simamora et al., 2021; Wilson et al., 2017; Yin et al., 2014). The various other reasons for replacement include poor functionality (Bai et al., 2018; Wieser and Troger, 2018), mobile phones being damaged (Borthakur and Singh, 2020; Li et al., 2012; Martinho et al., 2017; Ongondo and Williams, 2011a; Yin et al., 2014), out-of-date styles and functions (Martinho et al., 2017; Yin et al., 2014), etc. This has led to a massive surge in the generation of obsolete mobile phones.

The obsolete mobile phone e-waste is different in many ways when compared to other types of e-wastes. When users perceive the mobile phones that they use as obsolete, then the chances of them being replaced by new mobile phones are quite higher

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(Wieser and Troger, 2018). The in-use lifespan of smartphones is around 1.98 years and that of feature phones (non-smartphone mobile phones) is around 2.46 years (Abbondanza and Souza, 2019). Hence, it can be considered that many of the mobile phones entering into the e-waste stream can possibly have functional and economic value. Other than the shorter in-use lifespan, mobile phones are different when it comes to the storage post-usage phase by the users (Afroz et al., 2013; Cai et al., 2020; Martinho et al., 2017; Nowakowski, 2016), lesser repairability with just 13 smartphone models scoring 6 or above out of 10 in smartphone reparability score list (Smartphone Repairability Scores, 2021) prepared by a website named ifixit, the highest share of e-waste being generated despite having a low average weight of 0.3 kg per unit (Abbondanza and Souza, 2019), etc.

A mobile phone is composed of numerous valuable metallic elements like gold, silver, palladium, etc. (Maragkos et al., 2013). The adoption of inappropriate disposal methods like storing the mobile phones after the usage phase, throwing them along with the general waste, handing them to the informal recycling sector, etc. can lead to the loss of valuable metals. Hence for the success of a circular economy, recovery of those valuable metals is very much necessary. In addition, the recovery of those metals can also reduce the dependency on newly extracted raw materials. Or else a low return rate of end-of-life mobile phones will be a barrier to the recycling chain (Tanskanen and Butler, 2007). Metals like cadmium, lead, chromium, mercury, etc. are also toxic. The utilisation of unscientific methods of e-waste recycling leads to the reduction of the quality of air, water, soil and it even leads to hazardous effects on human health as well (Vaish et al., 2020). The lithium contents can lead to diseases like vomiting, muscular weakness, diarrhoea, etc. (Pathak et al., 2017). Pollutants like cadmium can lead to birth defects, and barium can lead to brain, heart, liver and lung damage (Pavithra et al., 2020). Hence, the adoption of sustainable methods to dispose of end-of-life/obsolete mobile phones is highly required. The various sustainable methods that users can adopt to dispose of their obsolete mobile phones include methods such as handing over mobile phones to formal recycling organisations, increasing the usage duration, reuse by others and repair.

Various review studies to analyse the situation of general e-waste have been carried out. Pérez-Belis et al. (2014) gave a broad review on e-waste management, generation, characterisation, socio-economic aspects as well as on re-use and recycling of general e-waste. Zhang et al. (2017) focused on the demand and supply of various critical elements that are present in electronic devices and even on the various methods that are utilised to recycle those critical metals. Ilankoon et al. (2018) examined the transboundary movement of e-waste, various international legislations and initiatives on e-waste as well as on various processes and technologies that are adopted to recycle various critical metals. Islam et al. (2021) gave a comprehensive review on consumer behaviour and awareness towards e-waste. The study even focused on the lifespan of various electronic devices, various factors affecting consumers' e-waste disposal decision and factors affecting e-waste recycling behaviour. Phulwani et al. (2021) conducted a comprehensive evaluation regarding consumer disposal behaviour towards personal communication devices such as mobile phones, laptops and tablets.

There are certain review studies that focused exclusively on mobile phone e-waste. Sarath et al. (2015) analysed various literature on generation and management of mobile phone e-waste, the economics of mobile phone recycling, toxicity assessment and recovery of various material contents in mobile phones. Xu et al. (2016) undertook a comparative assessment on mobile phone e-waste management in developed countries and in China. Yahya et al. (2021) summarised the existing knowledge on factors that affect mobile phone recycling through reverse supply chain management.

However, these reviews do not provide much detailed insights on aspects such as reasons for replacing mobile phones, various methods to dispose of them, in-use lifespan, the scope of reuse and various different factors that can play a role on consumers' behavioural intention to recycle their obsolete mobile phones. The aim of this review article is to undertake a comprehensive analysis of the contents of articles covering various important aspects regarding the issues related to obsolete mobile phone disposal by users. Analysis in this area is very much crucial as a result of widespread consumption as well as disposal of mobile phones around the world. The adoption of inappropriate disposal methods by users can cause hazardous impacts on the environment, human health and can even turn into a barrier to the circular economy. Several researchers have undertaken investigations on this issue, and it has resulted in a large number of research articles. The current review is based on the analysis of aspects, such as reasons for replacement of mobile phones, disposal methods adopted by the users, the in-use lifespan of mobile phones, reuse of obsolete mobile phones and behavioural intention, to recycle obsolete mobile phones.

The findings from such articles will be discussed in detail in the subsequent sections of this review.

Methods

The study was conducted through the literature review of various research articles in the field of the disposal of obsolete mobile phones by users/consumers. In addition, certain research articles, which were related to the general e-waste, also had to be reviewed because those studies even focused on end-of-life management of obsolete mobile phones along with other types of electronic devices. A detailed literature survey has been undertaken for articles published from the year 1999 to September 2021. A total of 210 research articles that focused on e-waste disposal were reviewed of which 109 research articles were cited in this study as they were relevant to the objectives of this study. Out of the 109 research articles that were cited, 61 research articles focused specifically on obsolete mobile phones. The remaining 48 research articles focused on various types of obsolete electronic devices including obsolete mobile phones. The research articles

for this review study were searched by utilising keywords like 'obsolete mobile phones', 'mobile phone waste', 'recycling', 'reuse', 'customer recycling behaviour', 'disposal behaviour', 'hibernation', 'E-waste' and 'end-of-life'.

Based on the literature survey, this review focused on five major aspects as follows:

A – Reasons for replacing mobile phones
B – Methods to dispose of obsolete mobile phones
C – In-use lifespan of mobile phones
D – Reuse of obsolete mobile phones
E – Recycling of obsolete mobile phones

Details of research conducted in each of the above five aspects have been discussed in the subsequent sections. Various research publications, books and proceedings published between 1999 and September 2021 were verified and taken into consideration for this review. Many of the research articles focused on two or more of the above mentioned five aspects.

Review content results

The main characteristics of each aspect are discussed in the following sections.

Reasons for replacing mobile phones

While assessing the various methods to dispose of obsolete mobile phones, one should first know why users/consumers are replacing their old mobile phones with new ones, as replacement is the root cause for disposal. Hence, several researchers have focused on the reasons for the replacement of mobile phones. However, the main reason for replacement is not uniform across various studies. Table 1 presents an overview of those studies.

From many works of literature reviewed, it was found that mobile phones being completely damaged or broken or being non-functional is the main reason (Borthakur and Singh 2020; Li et al., 2012; Martinho et al., 2017; Ongondo and Williams, 2011a; Yin et al., 2014). Wilson et al. (2017) categorised reasons for replacement into different forms of obsolescence such as functional obsolescence, technological obsolescence, absolute obsolescence, aesthetic obsolescence, societal obsolescence, psychological obsolescence, ecological obsolescence, economic obsolescence and service-orientated functional obsolescence. Technological obsolescence was found as the main reason for the replacement by students aged between 18 and 25 years in the UK.

In addition, reasons, such as theft of mobile phones (Li et al., 2012), desire for new models (Borthakur and Govind, 2019; Borthakur and Singh 2020; Martinho et al., 2017) and lack of repairability (Borthakur and Singh 2020), can also induce consumers to replace their mobile phones.

Table 1 portrays percentage-wise distribution regarding the reasons for replacement found from various literature. However, the aggregate percentage was not 100% in most of those studies. This is mainly as many users would have replaced more than one mobile phone and the main reason for the replacement of each mobile phone need not be the same. Hence, many users have marked multiple answers for the same question on the reason for the replacement of mobile phones at the time of data collection for various studies.

The main reason for the replacement of mobile phones can vary within a country from one period to another. For example, during the first half of the previous decade, the main reason for the replacement of mobile phones in China was because of the mobile phones being broken or completely damaged (Li et al., 2012; Yin et al., 2014), whereas during the second half, replacements happened mainly due to poor functionality even though those mobile phones were still usable (Bai et al., 2018; Tan et al., 2018). Similarly in the UK, it was due to mobile phones being broken (Ongondo and Williams, 2011a) and later on technological obsolescence was found as the main reason (Wilson et al., 2017). This is an indication that many users of those mobile phones can extend its in-use lifespan. If at all it is compulsory for them to replace, then those mobile phones can be collected and handed over for sustainable options such as repair, reuse, refurbishment and even for remanufacturing or recycling.

As the main reasons for the replacement of mobile phones are not the same around the world, and the main reason can change from one period to another within the same country, it will be necessary to frequently undertake research on this aspect periodically in each country.

Methods to dispose of obsolete mobile phones

A consumer/user can dispose of his/her obsolete mobile phones through various methods such as storing/hibernating them in post-usage phase, handing over to others for free or by selling, disposing of along with the general waste and exchanging it for availing discount while purchasing a new mobile phone. However, the adoption of methods, such as storing them in post-usage phase, disposing them along with the general waste and handing them over to the informal recycling sector, are unsustainable disposal methods. Hence, several researchers even focused on the disposal methods adopted by mobile phone consumers/users.

Table 2 presents findings from various studies about disposal methods adopted by users. The total percentage in various studies with regard to the disposal methods adopted is not 100%, mainly because a consumer in his/her life might have disposed of more than one mobile phone, and the disposal method adopted for each mobile phone need not be the same.

From various literature, it has been found that storing/hibernating mobile phones in post-usage phase is the most common method adopted by consumers/users. Consumers can store those mobile phones at home, office, etc. The storage of obsolete mobile phones is a serious concern for the circular economy and for the safety of the environment and human health. The storage makes the recovery of valuable metals more difficult (Tanskanen

Table 1. Studies that focused on various reasons for the replacement of mobile phones.

Study	Sample size	Location	Reason for replacement
Ongondo and Williams (2011a)	2287	UK	Phone being broken – 57.7% Upgrade from network operator – 41.1% Need for longer battery life – 18.1%
Li et al. (2012)	1011	Baoding, China	Phone being broken – 65.58% Poor functioning – 41.44% Phone being stolen – 37.29%
Babayemi et al. (2014)	509	Nigeria	Desire to have new/additional features – 49% Desire for phone with better accessories – 22% Phone being obsolete – 13% Phone being defective – 8% Phone lost – 8%
Yin et al. (2014)	1035	China	Phone being damaged – 43.8% Out of fashion functions and style – 37.1%
Wilson et al. (2017)	181	UK	Technological Obsolescence – 37.02% Functional obsolescence – 28.73% Economic obsolescence – 26.52%
Martinho et al. (2017)	386	Lisbon and Tejo Valley, Portugal	Phone being broken – 31% Desire for new models – 14% Out-of-date functions – 14%
Wieser and Troger (2018)	988	Austria	Phone being defective – 32% Current phone being better – 23% Previous one couldn't meet needs and expectations – 22%
Bai et al. (2018)	820	China	Poor functioning – 45.2% Phone being broken – 37.9% Outdated style – 8.8%
Tan et al. (2018)	296	Foshan, China	Poor functioning – 58.4% Phone being broken – 17.2% Phone lost – 8.1%
Borthakur and Govind (2019)	190	Bengaluru, India	Buying new mobile phone is better than spending heavily on repair – 68.1% Newly launched models with more attractive features – 53.8% Old one became non-functional – 48.3%
Borthakur and Singh (2020)	334	New Delhi, India	Becoming non-functional – 50% Unrepairability – 40% Buying new mobile phone is better than spending heavily on repair – 37%
Cai et al. (2020)	474	Zhuhai, China	Newly launched models with more attractive features – 39.4% Buying new mobile phone is better than spending heavily on repair – 26.6% Poor functioning – 15.4% Completion of lifespan – 10.7% Moving to a new house – 7.8%
Islam et al. (2020)	440	Sydney, Australia	Phone got damaged – 34% Backdated capacity – 26% Desire to have new/additional features – 23%

and Butler, 2007). This contributes towards the extraction of more non-renewable raw materials (Wilson et al., 2017). The small size of mobile phones makes it more prone to be stored (Duygan and Meylan, 2015; Li et al., 2012; Zhang et al., 2021).

Table 3 presents the research studies that focused on the percentage of users/consumers who stored their obsolete mobile phones and the reasons for storage. However, total percentage regarding various reasons for storage in many of the studies is more than 100% as many consumers could have possibly stored more than one obsolete mobile phone, and the reasons for the storage can vary from one mobile phone to another.

The percentage of people storing their obsolete mobile phones is not uniform across various studies. It can vary from one country to another during the same time period. For example, in 2017, in Lisbon and Tejo Valley of Portugal, it was just 36% (Martinho et al., 2017), whereas, in China, it was 52.2% (Tan et al., 2017), and in UK, it was 54.14% (Wilson et al., 2017).

Apart from this, the percentage of users/consumers storing their obsolete mobile phones can change in a country from one period to another. For example, in Poland, in 2016 it was 63% (Nowakowski, 2016). However, the storage percentage got increased to 80% in 2019 (Nowakowski, 2019).

Table 2. Mobile phone disposal adopted by consumers found across various studies.

Study	Sample size	Location	Method adopted
Ongondo and Williams (2011a)	2287	UK	Stored it – 55.7% Gave to someone as gift – 18.7% Donated for recycling – 9.4% Exchanged for discount on new phone – 5.2% Sold it – 3.1% Disposed it with general waste – 1.6%
Li et al. (2012)	1011	Baoding, China	Stored it – 64% Gave it to someone for free – 20% Sold it – 7% Disposed it with general waste – 3% Exchanged for discount on new phone –1%
Yin et al. (2014)	1035	China	Stored it – 47.1% Either gave to others or lost – 24.8% Disposed it with general waste – 6.8%
Kwatra et al. (2014)	)400	New Delhi, India	Stored it – 46% (stored it so that other family members can use it in future – 30%, just kept it with other old things – 16%) Sold it – 46% Throw it as waste if damaged – 4%
Ylä-Mella et al. (2015)	53	Oulu, Finland	Stored at home – 55% Gave them to the recycling centre – 18% Gave it to someone for free – 16% Leave them at store – 8.5% Sold them – 2.4%
Wilson et al. (2017)	181	UK	Stored it – 54.14% Gave it to friends/family – 17.68% Gave to recycling centre – 6.08% Sold it to store – 4.97% Stolen – 4.42% Sold it to individual – 2.76% Left at store while buying new – 1.66% Disposed it with general waste –1.1% Donated it to charity – 0.55%
Martinho et al. (2017)	386	Lisbon, Portugal Tejo Valley, Portugal	Stored it at home – 36% Gave it to producer responsibility organisations – 21% Gave it to friends/relatives – 4% Disposed it with general waste – 3%
Tan et al. (2017)	191	China	Stored it – 52.5% Gave it to relatives – 21.4% Handed over to recycling sector – 20%
Deng et al. (2017)	204 – households 893 – individuals	Hong Kong	Stored it at home – 75% Sold it – 75% Gave it to friends/relatives – 20% Disposed it with general waste – 16.7%
Wieser and Troger (2018)	988	Austria	Stored at home – 51.4% Donated for recycling – 17.2% Gave it as gift – 12.2% Sold it to other person – 6.7% Handed it to recycling centres – 1.9% Disposed it with general waste – 1.4%
Bai et al. (2018)	820	China	Stored at home – 79.3% Gave it to friends/relatives – 35.7 Sold them to scrap dealers – 6%
Tan et al. (2018)	296	Foshan, China	Stored at home – 62.1% Gave it to friends/relatives/charities – 12.7% Disposed it with general waste – 8.9% Handed to recycling channels of mobile phone manufacturers – 1.4% Handed to recycling channels of treatment enterprises – 0.8%
Nowakowski (2019)	388	Poland	Stored at home – 80%

(Continued)

Table 2. (Continued)

Study	Sample size	Location	Method adopted
Qu et al. (2019)	180	China	Stored at home – 30.5%
Borthakur and Singh (2020)	334	New Delhi, India	Stored at home – 50% Gave it to friends/family/relatives – 45% Sold them to scrap dealers – 30% Leave at store while buying new one – 28% Handed it to recycling centres – 16% Disposed it with general waste – 4.7%
Cai et al. (2020)	474	Zhuhai, China	Stored at home – 53.9% Sold to second-hand market – 15.4% Disposed it with general waste – 7.3% Sold to qualified enterprise – 7.2% Donated it to charity – 7.2% Exchanged for new phone – 5.6% Waiting for door-to-door delivery – 3.5%
Islam et al. (2020)	440	Sydney, Australia	Stored at home – 43.98% Took them to council collection points – 13% Disposed it with general waste – 11% Sold it – 10% Handed it to recycling centres – 9%
Inghels and Bahlmann (2021)	296	Netherlands	Stored at home – 61% Gave it to friends/relatives – 17% Sold it – 8% Lost or stolen – 5% Exchanged for new phone – 2% Handed it to recycling centres – 2% Gave it on rent – 2% Disposed it with general waste – 2%
Zhang et al. (2021)	596	Jiangsu, China	Stored at home – 49% Handed it for formal recycling – 25% Gave it to others – 19% Sold it – 4% Handed it for informal recycling – 2% Disposed it with general waste – 1%

Table 3. Findings from various studies regarding the percentage of consumers who store their obsolete mobile phones and the reasons for storing.

Study	Location	Percentage	Reason for storing the retired mobile phones
Ongondo and Williams (2011a)	UK	60%	To keep them as back-up phone – 78% Lack of knowledge on what to do with the phone – 30%
Li et al. (2012)	Baoding, China	64%	Lack of knowledge on what to do with the phone – 59.81% Inconvenient take-back services – 35.24% To keep them as back-up phone – 28.13%
Yin et al. (2014)	China	47.1%	Lack of knowledge on what to do with the phone – 45.9% To give them to friends/families in future – 28.3% Due to information security concern – 17.7%
Kwatra et al. (2014)	New Delhi, India	46%	Main reason – so that their family members can use those mobile phones
Ylä-Mella et al. (2015)	Oulu, Finland	55%	To keep them as back-up phone – 48.33% Did not involve in recycling or returning task for mobile phones – 33.33% Lack of knowledge on where to take them – 15%
Wilson et al. (2017)	UK	54.14%	To keep them as back-up phone – 75.18% Due to lack of worthiness – 28.37% Lack of knowledge on what to do with the phone – 26.24%
Martinho et al. (2017)	Lisbon, Portugal Tejo Valley, Portugal	36%	Lack of knowledge on where to take them – 24% To give them to friends/families in future – 21% To keep them as spare phone – 15%
Deng et al. (2017)	Hong Kong	75%	Main reason – lesser price in second-hand market

(Continued)

Table 3. (Continued)

Study	Location	Percentage	Reason for storing the retired mobile phones
Bai et al. (2018)	China	79.3%	Due to information security concern – 63.7%
Nowakowski (2019)	Poland	80%	To keep them as backup phone – 53% Least bothered about disposal – 10% It is a valuable device – 9%
Qu et al. (2019)	China	30.45%	Due to information security concern – 42.1% Lack of knowledge on how to dispose – 38.6% Insufficient monetary compensation – 33.5%
Inghels and Bahlmann (2021)	Netherlands	61%	Main reason: To keep them as spare/back-up phone

The main reasons for the storage also vary from one study to another. In some studies, it was found that users/consumers store those mobile phones mainly to keep those retired mobile phones as spare/backup mobile phones (Nowakowski, 2019; Ongondo and Williams, 2011a; Wilson et al., 2017; Ylä-Mella et al., 2015). From some studies, it was found that the lack of awareness regarding what to do with the obsolete mobile phones is the main reason (Li et al., 2012; Martinho et al., 2017; Yin et al., 2014). In addition, the concerns about information security (Bai et al., 2018; Qu et al., 2019) and intention to give those mobile phones to family members (Kwatra et al., 2014) were also found as the main reason for the storage of obsolete mobile phones.

The main reason for the storage need not be the same in a country forever. For example, in China, the main reason for storage was as a result of low consumer awareness with regard to what to do with obsolete mobile phones (Yin et al., 2014). However, later on, the concerns regarding information security became the main reason for the storage (Bai et al., 2018; Qu et al., 2019).

The percentage of users/consumers choosing other disposal methods can differ from one country to another. For example, the percentage of users/consumers handing over their obsolete mobile phones to recycling centres in the UK is 6.08% (Wilson et al., 2017), in New Delhi, India it is 16% (Borthakur and Singh, 2020) and in Austria it is 19.1% (Wieser and Troger, 2018). In the UK, just 1.66% of users/consumers exchange their old mobile phones for a discount at the time of purchase of new mobile phones (Wilson et al., 2017), whereas in Bengaluru, India it is 22.1% (Borthakur and Govind, 2019) and in New Delhi, India it is 28% (Borthakur and Singh, 2020). This higher return of old mobile phones while purchasing new mobile phones is mainly under the exchange offer schemes. This method adopted by the Indian consumers can be furthermore motivated through extended producer responsibility (EPR) measures adopted by the manufacturers (Borthakur and Govind, 2019).

As mobile phones are small in size, it is very easy to dispose of them along with the general waste and it will be difficult to detect those thrown away mobile phones in municipal solid waste (Geyer and Blass, 2010). However, from most of the studies, it can be seen that the percentage of users/consumers throwing mobile phones along with general waste is lower than 5%, with certain exceptions like 6.8% of the users/consumers in China (Yin et al., 2014), 8.9% of the consumers in Foshan, China (Tan et al., 2018), 11% of the consumers in Sydney, Australia (Islam et al., 2020) and 16.7% of the consumers in Hong Kong (Deng et al., 2017).

The lack of uniform findings across various studies regarding the percentage of people adopting several disposal methods makes it necessary to focus more on disposal methods in future studies that would deal with mobile phone disposal behaviour.

In-use lifespan of mobile phones

It is highly unlikely that a person can use the same mobile phone throughout his/her life. So, at one point or the other, all of it will have to be disposed of and will be replaced by new mobile phones (Osibanjo and Nnorom, 2008). Hence, replacing a mobile phone with another one is a very common phenomenon. Amongst the 3Rs of sustainability, over here, 'reduce' is mainly about reduction of mobile phone replacement frequency. Increase in in-use lifespan is the most important way through which the replacement frequency can be reduced. Due to this, the in-use lifespan of mobile phones has also been one of the important aspects related to the disposal of obsolete mobile phones.

Rapid innovation and launch of mobile phones, especially smartphones with newer features and the sellers' desire to increase their turnover (Tu et al., 2018) and consideration of mobile phones as fashionable products by consumers lead to the reduction of in-use lifespan of mobile phones (Liu et al., 2019; Thavalingam and Karunasena, 2016). This turns many mobile phones obsolete or to be considered as obsolete, and as a result of this, many users/consumers replace those obsolete mobile phones with new ones. Hence, it is necessary that the in-use lifespan of mobile phones should get increased for the benefit of environment and for better human health.

Table 4 presents the in-use life span of mobile phones found across various studies. The in-use lifespan of mobile phones is not the same in every country. For example, in 2018, in Austria, it was 3 years (Wieser and Troger, 2018); in China, it was 2.24 years (Bai et al., 2018) and in the USA, it was 2.8 years (Sabbaghi and Behdad, 2018). It can vary within a country as well. As mentioned earlier, the average lifespan of mobile phones in China was reported with 2.24 years (Bai et al., 2018), whereas in Foshan, China, it was 1.54 years (Tan et al., 2018). In

Table 4. In-use lifespan of mobile phones found in various studies.

Study	Aimed at	Location	Average in-use lifespan
Huang et al. (2006)	General consumers	Ningbo, China	0.5 year – 5% 0.5–1 years – 21% 1–2 years – 44% >2 years – 30%
Gurauskienė (2008)	Life span data from a secondary source	USA	2 years
Jang and Kim (2010)	General consumers	South Korea	2.4 years
Ongondo and Williams (2011a)	University students	South-East England, UK	1 year
Li et al. (2012)	University students	Baoding, China	2 years
Fraige et al. (2012)	Households	Jordan	3.5 years
Polák and Drápalová (2012)	Mobile phone devices	Czech Republic	3.63 years
Kim et al. (2013)	Households	South Korea	2.07 years.
Yin et al. (2014)	General consumers	China	3 years
Chi et al. (2014)	General consumers	Taizhou City, China	2.8 years
Ylä-Mella et al. (2015)	General consumers	Oulu, Finland	2–3 years
Cao et al. (2016)	General consumers	Zhejiang, China	3 years
Echegaray (2016)	General consumers	Brazil	2.6 years
Maheswari et al. (2017)	General consumers	Indonesia	2.57 years
Wilson et al. (2017)	Students (18–25 years old)	UK	1.91 years in in-use 3 years in hibernation.
Martinho et al. (2017)	General consumers	Lisbon, Portugal Tejo Valley, Portugal	2.7 years (smartphones only).
Tan et al. (2017)	General consumers	China	Less than a year – 9.4% 1–2 years – 40.3% 2–3 years – 30.9% More than 3 years – 19.4%
Deng et al. (2017)	Households	Hong Kong	1.91 years
Thiébaud et al. (2017)	General consumers	Switzerland and Liechtenstein	3.3 years
Wieser and Troger (2018)	General consumers	Austria	3 years
Bai et al. (2018)	General consumers	China	2.24 years
Sabbaghi and Behdad (2018)	General consumers	USA	2.8 years
Tan et al. (2018)	General consumers	Foshan, China	1.57 years
Liu et al. (2019)	General consumers	China	2.21 years
Borthakur and Govind (2019)	General consumers	Bengaluru, Karnataka, India	1–2 years – 20% 2–3 years – 46.4% 3–4 years – 33.6% More than 4 years – 0
Zhang et al. (2020	University students	Jiangsu Province, China	1.6 years
Abbondanza and Souza (2019)	General consumers	Sao Jose dos Campos, Brazil	Smartphones – 1.78 years Non-smartphones – 2.29 years
Borthakur and Singh (2020)	General consumers (age: 18–21)	New Delhi, India	0–1 year – 4.19% 1–2 years – 28.14% 2–3 years – 26.35% 3–4 years – 14.37% Beyond 4 years – 27%
Inghels and Bahlmann (2021)	University students and their relatives	Netherlands	1.33 years

India, the percentage of consumers who have replaced their mobile phones within 2 years in Bengaluru is 20% (Borthakur and Govind, 2019), whereas in New Delhi, it is 32.33% (Borthakur and Singh, 2020).

The in-use lifespan of mobile phones can be increased through reuse by handing over those obsolete mobile phones to others for free or by sale. However, many people even have reservations regarding the acceptance of second-hand mobile phones due to reasons such as lack of reliability, short life cycle, presence of new budget price models and lack of warranty (Ylä-Mella et al., 2015).

Repair of mobile phones that have got damaged or got performance-related issues will also be helpful to increase the in-use lifespan of mobile phones as the successful repair works can reduce the possibility of buying a new mobile phone in the near future (Sabbaghi and Behdad, 2018).

However, Makov et al. (2018) found that reparability of smartphones caused only marginal impact on the expansion of

in-use lifespan as well as on reuse. The study involved analysis of 500,000 listings of already used Apple and Samsung smartphones, which were sold during the first quarters of 2015 and 2016 through eBay.com. Unfavourable factors, such as high repair costs and even consumers' belief that mobile phones cannot be successfully repaired, can also act as a barrier to the extension of the in-use lifetime (Wieser and Troger, 2018).

To study the durability of smartphones, Cordella at al. (2021) undertook a technical analysis on the reliability and repairability aspects of smartphones. They recommended that increasing the reliability and repairability of smartphones will be helpful to increase its lifetime. To increase reliability, the smartphone designs should possess the capability to resist mechanical stresses, the battery should be durable, should be more adaptable to update software/firmware and to upgrade the memory and storage capacity. To increase repairability, repair facilities should be rapid and economically viable. Developing smartphones with modular designs, increasing easiness to disassemble internal parts (as well as the availability of spare parts) and the presence of repair services will play an integral role to increase repairability. More importantly, it is necessary to educate consumers by providing them required information on ideal usage, maintenance and repair of their smartphones. Makov and Fitzpatrick (2021) found that in addition to technical aspects, non-technical aspects, such as mental depreciation and perceived obsolescence, also play a vital role in determining the in-use lifespan of smartphones.

The in-use lifespan of mobile phones should be focused on while studying disposal behaviour as the in-use lifespan is not universal throughout the world and its getting decreased as well. Along with this, future studies should even focus on methods to increase the in-use lifespan, and the role that users/consumers as well as various other stakeholders, such as manufacturers, channel members and governments, can play to increase the in-use lifespan. This is highly essential because many of the researchers who have focused on in-use lifespan did not focus much on ways to increase it. Hence, future studies should focus even on methods to increase the in-use lifespan.

Reuse of obsolete mobile phones

Reuse is one of the 3Rs of sustainability. Reuse of obsolete mobile phones means handing over those mobile phones by users/consumers to others for free or by sale (Rahmani et al., 2014). It can even happen when the mobile phone manufacturers, retailers and others resell or donate the mobile phones that they have received back through various take-back or exchange schemes. This contributes towards the extension of the in-use lifespan of mobile phones (Makov et al., 2018; Riisgaard et al., 2016; Wilhelm et al., 2015; Xu et al., 2016; Yin et al., 2014).

The take-back collection can happen as a result of original equipment manufacturers collecting them directly from the users/consumers, collection from the drop-off points where users/consumers can deposit their obsolete electronic devices, collection through specialist local collection schemes, etc. (McLaren et al., 1999). The take-back schemes help to reroute the obsolete mobile phones from landfills and hence increases the scope for reuse and recycling (Ongondo and Williams, 2011b).

Reuse is also considered as an inner circle of the circular economy (Riisgaard et al., 2016). High-level participation from the side of users/consumers is necessary for the success of the circular supply chain or else it can disturb the long-term success of the circular economy (Canning, 2006). The higher reuse rate also decreases dependency on newly extracted raw materials (Hankammer et al., 2017; Velmurugan, 2016; Wilhelm et al., 2015). This leads to improvement of resource efficiency (Guo and Yan, 2017). Hence, reuse is considered as a basic sustainable practice along with the reduction of replacement frequency and recycling (Makov et al., 2018).

From an economical perspective, the reuse market is a more economically beneficial one for the companies when compared to the recycling market. To avail the economic benefits of reuse, it is necessary to have improved mechanisms for the take-back of mobile phones within a short time period after the use phase (Suckling and Lee, 2015). In addition, reuse of second-hand mobile phones can even help people who cannot afford to purchase first-hand mobile phones as the second hand-mobile phones can be sold at lesser price (Shankul and Bhumarker, 2017; Velmurugan, 2016). The parts of those obsolete mobile phones, which cannot be repaired or being too old can be reused for manufacturing new electronic equipment (Velmurugan, 2016).

Despite so many benefits, reuse of obsolete mobile phones is still the second most disposal method adopted by the users/consumers (Table 1). Storage in post-usage phase is the most common disposal method. Users/consumers replacing their mobile phones as a result of technological obsolescence is a very common phenomenon (Cooper and Gutowski, 2015). The low readiness to receive second-hand mobile phones by many users/consumers and at the same time high readiness to hand on or sell the used phones leads to an increase in the storage of more mobile phones by users/consumers (Wieser and Troger, 2018). Hibernation of such mobile phones is an important barrier to reuse (Nowakowski, 2019; Zufall et al., 2020). The reuse potential is even dependent on the mobile phone's functional and aesthetic conditions as well as the presence of a secondary market. Hence, it is very much necessary to collect those retired mobile phones as early as possible because their value and opportunity to reuse gets reduced rapidly as time moves on (Hanks et al., 2008; Geyer and Blass, 2010). Physical durability, standardised components, reversible joints that allow easy disassembly, mature technology and design (Cooper and Gutowski, 2015) as well as modular designs that allow for upgrading and repair enables the reuse of obsolete mobile phones (Cooper and Gutowski, 2015; Hankammer et al., 2017; Proske and Jaeger-Erben, 2019).

Low users/consumer awareness on what to do with their obsolete mobile phones also turns into a barrier for both reuse and recycling (Li et al., 2012; Martinho et al., 2017; Yin et al., 2014). Hence, it is very much necessary to educate the people

about the importance of reuse along with educating them about recycling (Nguyen et al., 2019; Wang et al., 2011). Hence, sound knowledge and awareness about e-waste are required for increasing safe disposal methods such as reuse and recycling (Miner et al., 2020).

As mobile phones today are multi-purpose devices that help people to fulfil a lot of needs in their regular life like mobile banking, social media usage, capturing and storing photographs, etc., the concern regarding information security issues has also become crucial. Hence, concern regarding information security is also a barrier for reuse (Bai et al., 2018; Li et al., 2012; Qu et al., 2019; Wilson et al., 2017; Yin et al., 2014). Electronic erasure of information can be helpful to reduce information security-related concerns and this, in turn, can be helpful to increase the possibility of reuse (Mishima and Nishimura, 2015).

Most of the researchers while focusing on the reuse of obsolete mobile phones did not give that much attention to it when compared to recycling. In many of the studies, reuse was just a minor aspect that was focused upon. Due to this, even though many researchers were able to find out the causes that hinder the reuse of obsolete mobile phones, more focus is necessary to develop appropriate solutions to increase reuse. Hence, in future studies, researchers should increase their focus on reuse and even exclusive studies on reuse should also be undertaken to increase reuse.

Recycling of obsolete mobile phones

Handing over obsolete mobile phones to formal recycling centres is considered as a favourable way of disposal, as recycling is one among the 3Rs of sustainability. Recycling, remanufacturing and refurbishing are considered as outer circles of the circular economy (Wieser and Troger, 2018). Successful reverse logistics is required to recapture value and for the recovery of metals. Those mobile phones that got returned back to the system can be utilised for various options like recycling, reuse, remanufacturing, refurbishment, etc. (Chan and Chan, 2008). But low return rate of obsolete mobile phones obstructs the recycling chain (Tanskanen and Butler, 2007). As the recycling rate of mobile phones is very low, many researchers have focused on behavioural intention of users/consumers to recycle their obsolete mobile phones. Some of those works, which focused exclusively on recycling of obsolete mobile phones, as well as those which focused on the recycling of general e-waste, are discussed in this section. The sub-sections of this section are divided according to various factors that were taken into consideration by various researchers. Following are the various factors that can influence behavioural intention of consumers to recycle their obsolete mobile phones:

Awareness and attitude. Consumers' awareness about and attitude towards recycling has been considered as one of the important factors in several studies. This is mainly because, the disposers' lack of knowledge, and being unconcerned about how waste will be treated and its negative consequences is one of the important concerns of waste management (Shinkuma and Managi, 2012). Hence, increase in user/consumer awareness on e-waste management system is very much essential (Bhat and Patil, 2012).

When it comes to awareness and knowledge of users/consumers regarding e-waste, low public awareness, especially on e-waste of smaller electronic devices, leads to lesser customer engagement (Darby and Obara, 2005). Hence, education on conservation of resources and environmental protection should be provided from the elementary education level. Therefore, they can learn about e-waste recycling habits from their childhood (Wang et al., 2011). The educated people, especially graduates and even those who have higher qualification, can put efforts to increase awareness among the people who are living in their locality (Bhatia et al., 2019). The information on e-waste recycling can be diffused even through various social media platforms as well (Delcea et al., 2020).

Sivathanu (2016) surveyed 600 consumers of electronic devices in Pune, India. It was found that awareness of toxic effects on human health, awareness of environmental hazards, awareness of proper disposal of e-waste, awareness of e-waste management by various stakeholders and awareness of convenience of recycling are the five awareness factors that contribute towards consumers' preferences at the time of disposal of e-waste.

When it comes to mobile phone recycling, Nnorom et al. (2009) studied the willingness of residents in Nigeria to participate in the recycling of obsolete mobile phones. The data was collected from 1000 residents staying in two towns near Uturu, Nigeria. From the study, it was found that awareness of the ongoing environmental degradation and related concerns motivates the residents to participate in recycling programmes, and it raises their willingness to pay (WTP) extra for green electronics. But the study did not focus much on various other factors such as subjective norm, cost of recycling and the role of the informal recycling sector.

Welfens et al. (2013) surveyed 717 scholars aged between 9 and 18 years living in North Rhine-Westphalia, Germany. They found that young users/consumers' knowledge of the importance to recycle as well as how and where to return their obsolete mobile phones is low, and this low-level knowledge will turn into an obstacle for recycling. Hence, raising user/consumer awareness on this matter is very important. However, the study did not give much insight into mobile phone users/consumers of age above 18. The study also did not focus much on various other factors such as subjective norms, cost of recycling and role of the informal recycling sector.

Afroz et al. (2020) utilised the theory of planned behaviour (TPB) to study the intention of households living in Klang Valley, Malaysia to drop off their obsolete mobile phones to collection boxes to recycle. Responses from 525 samples were utilised, and it was found out that environmental knowledge and awareness positively influences attitude to recycle. As a result, recycling attitude positively influences households' behavioural intention to recycle their obsolete mobile phones. Due to this, they suggested that the households should be provided with relevant

information on the merits of recycling as well as methods, location and incentives for appropriate disposal. However, the study was limited to factors such as environmental awareness, attitude, subjective norm, cost of recycling and convenience of recycling.

Liu et al. (2019) studied various factors that hinder the recycling of obsolete mobile phones in China. Their study was based on TPB. In total, 1380 residents in China were surveyed. It was found out that environmental responsibility positively influences recycling attitude and plays an influential role on recycling intention. Regarding the role of awareness, it was found that various measures to recycle can be implemented efficiently only when users/consumers have full knowledge on e-waste. Therefore, they suggested that citizens should be provided environmental education so that their self-abilities and self-responsibilities can be reinforced favourably. Even though the study considered several factors, very few variables were considered for each factor. Zhang et al. (2020) also found that recycling attitude positively influences recycling intention of users/consumers in Hefei, China. Responses of 802 respondents were considered for the study. However, this study based on TPB did not focus much on user/consumer awareness.

Safitri and Kusumastuti (2020) studied mobile phone recycling intention of students and employees in Greater Jakarta, Indonesia. Amongst the various factors considered by them in TPB model, when it comes to the role of attitude, it was found that though many users/consumers do consider recycling as a favourable activity, the consideration need not motivate them to develop behavioural intention to recycle. But when it comes to the sample size considered for analysis, they considered the responses of just 169 respondents.

The common findings regarding awareness is almost the same in various studies that focused on recycling of obsolete mobile phones. However, contradicting findings have been found when it comes to attitude. Hence, future studies should not ignore attitude factor while studying the behavioural intention of consumers to recycle obsolete mobile phones.

Subjective norm. Subjective norm is mainly related to the social pressure that influences the perception of a person regarding whether to undertake a certain behaviour or not (Ajzen, 1991). The personal norms of a person can be influenced by those that are very much close to a person, such as family members and friends, can influence the personal norms at that person (Wang et al., 2018; Welfens et al., 2016). The subjective norm can act as a facilitator of recycling behaviour if others in the social network have also given their mobile phones for recycling and vice-versa (Welfens et al., 2016).

However, there have been contradicting findings on the influence of the subjective norm on behavioural intention to recycle obsolete mobile phones. In the studies by Safitri and Kusumastuti (2020) and Zhang et al. (2020), it was found that an individual's recycling intention is positively impacted by his/her social network, whereas from the study by Kumar (2017) and Afroz et al. (2020), it has been found that the subjective norm does not play much influential role in an individual's recycling intention.

As contradicting findings were found when it comes to the role of subjective norms in various studies, role of subjective norms should never be ignored in future studies focusing on behavioural intention to recycle obsolete mobile phones.

Recycling convenience. Recycling convenience is mainly about convenience for users/consumers in terms of facilities, time and proximity to handover recyclable products to formal recycling sector. Recycling convenience is one of the factors that have a significant impact on e-waste recycling behaviour (Dwivedy and Mittal, 2012; Wang et al., 2011).

However, results regarding the role of recycling convenience is not uniform across the studies specific to mobile phones. Liu et al. (2019) and Afroz et al. (2020) found that the convenience of recycling facilities is a key factor that has an impact on behavioural intention of recycling of obsolete mobile phones. The provision of more convenient facilities for hand over will be helpful to convert behavioural intention to recycle into recycling habit (Safitri and Kusumastuti, 2020). However, Zhang et al. (2020) and Simamora et al. (2021) did not find any significant impact.

Hence, more studies should focus more on the impact of recycling convenience on consumers' behavioural intention to recycle obsolete mobile phones.

Cost of recycling. The cost of recycling is also a significant factor that influences e-waste recycling behaviour (Dwivedy and Mittal, 2012; Wang et al., 2011). However, the viewpoints like e-waste recycling are the responsibility of government, lower-income group people finding it difficult to pay the e-waste disposal charges, etc. reduces consumers' 'WTP' for e-waste recycling (Song et al., 2012). However, Nguyen et al., (2019) reported that the cost of recycling has positively influenced the behavioural intention to recycle mainly as a result of higher awareness about the harmful contents in e-waste. When it comes to mobile phones, though cost of recycling plays a positive role, the positive role is not sufficiently significant enough to make an impact on recycling intentions (Afroz et al., 2020).

To the best of authors' knowledge, among the various studies that focused on behavioural intention to recycle obsolete mobile phones, only Afroz et al., (2020) considered cost of recycling as a separate factor. Hence, future studies should focus more on the role played by this cost on behavioural intention to recycle obsolete mobile phones.

Risk perception related to information security. Earlier mobile phones were utilised only for making phone calls and basic versions of text messaging. However, due to rapid technological innovations, modern mobile phones became a multi-purpose device that serves many purposes such as mobile banking, online shopping, social media usage, capturing and storing photographs, and recording videos. As a result of this, much personal secretive information gets stored on mobile phones. Due to this, research works on the role of information security concerns are getting increased.

Consumer's risk perception regarding information security misuse by other parties has become a very much important issue,

and it demotivates consumers to hand over their obsolete mobile phones for reuse and recycling (Bai et al., 2018; Li et al., 2012; Liu et al., 2019; Qu et al., 2019; Wilson et al., 2017; Yin et al., 2014). Bai et al., (2018) found that risk perception on this matter exists in the mind of many users/consumers even after deleting a lot of content as there is a possibility that those deleted contents can be illegally recovered by other parties. Zhang et al. (2020) found that even those individuals who have got higher conscientiousness also need not have a favourable attitude towards smartphone recycling when the risk perception regarding information security is high. However, Zhang et al. (2021) found that information security concerns influence the behavioural intention to recycle in a direct positive manner. Various measures, such as various stakeholders in formal recycling increasing their efforts to protect the consumers' privacy, establishment of certification standards for secure erasure of data and increasing publicity to ensure consumers' privacy, will be helpful to reduce the consumers' risk perception related to information security.

Even though there are many research works that focused on the impact of information security concerns on consumers' decision to undertake formal recycling, only few research works focused on information security concerns as an important aspect. Despite this, the contradictory findings on the role of information security concerns have been found out. Hence, it is essential to undertake studies with a wider focus on the role of information security concerns and its impact on reuse and recycling.

Social media. Globally, there are nearly 4.33 billion active social media users. This is nearly 55.1% of the world population, and on an average a social media user spends nearly 2 h and 22 min per day on social media (Kemp, 2021).

Wernink and Strahl (2015) recommended that social media platforms can be utilised to encourage consumers to use their mobile phones for a longer time period. The diffusion of a message to increase the in-use lifespan can happen when they share such messages or information with others. Welfens et al. (2016) suggested that social media can be utilised to motivate users/consumers to hand over their obsolete mobile phones to formal recycling channels. The comments and posts by others about e-waste recycling influence people positively to change their mindset.

However, the research on the impact of social media on behavioural intention to recycle obsolete mobile phones is very much limited. Hence, future research works can focus on the role of social media, as social media is used by many people worldwide.

Informal recycling sector. The transfer of e-waste from users/consumers to the informal recycling sector is very much common in India and in China mainly because informal recycling units can be easily set up and can be operated even under a small profit margin (Awasthi and Li, 2017). However, recycling e-waste by the informal recycling sector has several disadvantages as explained below.

It contributes to the degradation of the environment and human health (Rathore et al., 2011). In addition, it acts as a barrier for the implementation of EPR (Dwivedy and Mittal, 2012) mainly due to loss of resources at the time of the material recovery process (Pathak et al., 2017). Hence, e-waste recycling undertaken by the informal recycling sector cannot be considered as a sustainable method of recycling (Pathak et al., 2017).

Wang et al. (2016) found that service convenience and the incentives offered by the informal recycling sector motivate users/consumers to hand over their obsolete electronic devices to informal recycling sectors in China. They also found that perception of informal recycling negatively influences residents' behavioural intention to recycle their e-waste. However, this study focused on general e-waste.

Zhang et al. (2021) recommended certain measures to improve the participation of mobile phone users/consumers through the formal recycling. Those measures include an increase in the role of government to create a favourable social atmosphere to increase the participation in formal recycling through local newspapers, advertising, proper diffusion of messages through social media, etc. The convenience of formal recycling channels in rural areas should also be improved, and the formal recycling channels should increase their focus to improve the protection of privacy of information at the time of recycling.

Simamora et al. (2021) surveyed consumers in Indonesia who have replaced their old mobile phones with new ones. It was found that the influence of perception of informal recycling helps to implement the mobile phone e-waste management positively and this, in turn, leads to the increase of behavioural intensity to recycle obsolete mobile phones.

Even though Simamora et al. (2021) focused on the role of perception of the informal recycling sector, the sample size of the study was just 165 consumers. The study by Zhang et al. (2021) have focused to improve the formal recycling sector, but the role of the informal recycling sector was not considered as a separate factor in the conceptual model based on TPB that was utilised for that study. Most of the studies that focused exclusively on the recycling of obsolete mobile phones hardly focused on the role of informal recycling sectors.

Hence, future studies can even take the informal recycling sector into consideration to study its role on behavioural intention to recycle obsolete mobile phones through the formal recycling sector, especially to verify how the informal recycling sector turns into a barrier for recycling obsolete mobile phones through the formal recycling sector.

Laws and regulations. The successful implementation of e-waste oriented rules and regulations is very much important (Awasthi and Li, 2017) as it will be helpful for the reduction of e-waste-related hazards as well as precious metal recovery (Pathak et al., 2017). Amongst the various variables creating an impact on behavioural intention to recycle general e-waste, laws and regulations were found as the most important factor (Nguyen et al., 2019). Liu et al. (2019) recommended that the government should encourage green consumption and should strengthen legislations that deals with eco-designed products. Islam et al.

(2021) suggested about the need for formulation and implementation of regulatory frameworks focusing on informal recycling sector, EPR, etc. To achieve better circulatory of materials, the government should adopt measures such as provision of tax relief and subsidies to local recycling companies. In addition, the cooperation between the manufacturers of electronic devices and local waste management authorities should be increased.

He et al. (2021) projected that from 2020 to 2035, 1.7 billion units of out-of-use feature phones and 1.64 billion units of out-of-use smartphones will be generated in India. Due to this, certain recommendations that the Indian government can implement have been provided. Those recommendations include the formulation and regulation of e-waste recycling, recognition of the strategic significance of critical high-tech minerals present in mobile phones, implementation of policies for circular and sustainable e-waste recycling system and investment of the funds of the union government to support e-waste recycling activities through online mode.

The study by Nguyen et al. (2019) considered laws and regulations as a separate factor in the TPB-based conceptual model to study intention to recycle general e-waste. However, to the best of authors' knowledge in none of the studies specific to the recycling of obsolete mobile phones, law and order was considered as a separate factor in the TPB-based conceptual model. Hence, future studies can include law and order as a separate factor in TPB-based conceptual model or any other theory-based relevant conceptual model.

Past experience. Some of the users/consumers might have already handed over their obsolete mobile phones or other types of e-waste to formal recycling. Hence, studying the role played by their past experience on their behavioural intention to recycle their obsolete mobile phones is also important.

Saphores et al. (2012) found that those households in California, USA who have undertaken e-waste dropping-off in the past have got comparatively more desire to get their e-wastes recycled at the drop-off centres when compared to those who have not. Wang et al. (2018) also found similar results in China. However, Nguyen et al. (2019) found that among the residents in Da Nang, Vietnam, there is no direct relationship between past recycling experience and behavioural intention to recycle. The past experience indirectly influences through the inconvenience of recycling. That too the influence is negative in a weaker manner. These studies focused on general e-waste.

When it comes to the recycling intention, specifically regarding smartphones, Zhang et al. (2020) found that past experience positively influences the recycling intention of the users/consumers in Anhui, Province of China.

Very limited studies that focused exclusively on the recycling of obsolete mobile phones took past experience into consideration. Due to this, for future studies, past experience should be taken into consideration to obtain insights from those who have already handed over their previous mobile phones for recycling.

Incentives. As the entry of e-waste including obsolete mobile phones to various formal end-of-life channels is low, many research works focused on various types of economic incentives that can be offered to the users/consumers to motivate them to hand over their obsolete electronic devices.

++++Users/consumers usually are in favour of the concept 'beneficiary pays' as they consider that by returning their obsolete electronic devices they are providing something valuable to the manufacturer. They also prefer to receive incentives for undertaking responsible disposal behaviour (Phulwani et al., 2021). The incentives can be of various forms like offering a discount at the store at the time of purchase of new mobile phones while exchanging them with old ones (Maragkos et al., 2013; Rathore et al., 2011; Tan et al., 2018), monetary rewards (Botelho et al., 2016; Mishima and Nishimura, 2015; Silveira and Chang, 2010; Welfens et al., 2016; Zufall et al., 2020), providing coupons or reward points for recycling, which can be redeemed in the future (Botelho et al., 2016; Silveira and Chang, 2010; Tan et al., 2018), etc. Shevchenko et al. (2019) recommended for the implementation of electronic bonus card system (EBCS), which grants opportunity to accumulate bonuses, and those accumulated bonuses can be exchanged while purchasing a new planned product without any incurrence of additional charges. However, for the successful implementation of EBCS, the involvement of various stakeholders, such as the authorities, manufacturers, retailers, consumers, e-recyclers, collectors and the provider of the EBCS, is necessary.

Zhang et al. (2019) undertook a comparative study on the role of different types of compensation as a motivator to return obsolete mobile phones. Cash compensation was found as the more influential mode of compensation when compared to courier coupons and daily necessities.

Sari et al. (2021) utilised TPB to verify the consumer intention to participate in e-waste collection programmes. The study was undertaken in Indonesia with a sample size of 324 smartphone users. However, contradicting finding on the role of economic incentives was found in this study. It was found that economic incentives does not encourage the intention of consumers to participate in e-waste collection programmes. This is mainly because many consumers have the desire to hand over their smartphones to the collection centre without keeping any expectation to receive incentives. This finding was asserted as economic incentives received mode values of three points on a five-point Likert scale that was utilised to measure agreeableness. A Likert scale is a measurement scale that researchers use to collect respondents' attitudes and opinions towards a question or a statement. A five-point Likert scale question provides five options for the respondents to choose from the question. For example, strongly disagree, disagree, neutral, agree and strongly agree.

More research can be undertaken by including incentives as a separate factor in TPB-based conceptual model or any other relevant theory-based conceptual model because in a very limited number of research works that focused on the recycling of obsolete

mobile phones, incentives have been considered as a separate factor in the conceptual model.

Role of socio-demographic variables. Socio-demographic variables, such as gender, age, income, education level and family size, were considered for various research studies on e-waste management. However, the findings regarding the role of many of the socio-demographic variables are not uniform throughout every study.

Gender: From some of the studies, it has been found that women have relatively more willingness to recycle e-wastes than men (Borthakur and Govind, 2019; Echegaray and Hansstein, 2017; Nguyen et al, 2019; Saphores et al., 2006, 2012). However, from studies in China, it has been found that gender does not have any significant influence on behavioural intention to recycle e-waste (Wang et al., 2016, 2018).

Age: From some of the studies, it has been found that willingness to recycle e-waste increases as age increases (Borthakur and Govind, 2019; Saphores et al., 2012). However, there are studies from which it has been found that age does not have any significant influence on behavioural intention to recycle e-waste (Nguyen et al, 2019; Wang et al., 2016, 2018).

Education level: In Da Nang, Vietnam it was found that education level positively influences behavioural intention to recycle e-waste (Nguyen et al., 2019). However, studies in China by Wang et al. (2016) and Wang et al. (2018) disapproved the role played by education level on behavioural intention to recycle e-waste.

Family size: Saphores et al. (2012) had undertaken a national survey on the household in the USA. From the survey, they found that the larger the size of the family, the more the possibility of recycling e-waste. However, in the study conducted by Martinho et al. (2017) at Lisbon and Tejo Valley, Portugal, it was found that families with larger sizes have more knowledge about the presence of numerous valuable metals that are present inside the smartphones. However, this knowledge about the presence of valuable metals induces them to store their broken smartphones in their home instead of handing them over to formal recycling organisations.

Income level: Wang et al. (2016) found that the income of residents negatively influences their behavioural intention to recycle e-waste. However, from the study by Nguyen et al. (2019), it was found that the income of residents does not have a significant impact on behavioural intention to recycle e-waste.

Most of the studies discussed above which focused on the impact of socio-demographic variables on intention to recycle focused on general e-waste. As uniform results were not found, future studies that focus exclusively on the behavioural intention of users/consumers to recycle obsolete mobile phones should consider the impact of socio-demographic variables as well.

From the above discussions in this section, it can be observed that the number of research works that focused exclusively on consumers' behavioural intention to recycle obsolete mobile phones is lower when compared to the research works undertaken to study consumers' behavioural intention to recycle general e-waste. When it comes to findings on factors affecting behavioural intention to recycle general e-waste as well as mobile phones, contradicting findings on certain factors were found in various studies. Therefore, future studies should include these factors as well. The studies that exclusively focused on the recycling of obsolete mobile phones mainly utilised extended conceptual models based on the TPB. However, those studies did not include factors, such as incentives, past experience, informal recycling sector, social media, as well as laws and regulations, as separate factors. Due to this, the future researchers who undertake research based on conceptual model for hypothesis testing should include these factors as well. In addition, more relevant theories can also be combined with TPB in their conceptual model.

Analysis of the literature review

An overview of various research articles discussed so far gave summarised insights on various findings regarding the disposal of obsolete mobile phones by consumers. Figure 1 shows the number of articles on e-waste by year that were reviewed and cited in this study. The set of articles in Figure 1 includes those articles, which focused exclusively on obsolete mobile phones and those which focused on various types of obsolete electronic devices including obsolete mobile phones. Figure 2 shows the number of articles by each year that focused exclusively on obsolete mobile phones that were reviewed and cited in this study. From Figure 2, it can be found that only one research work on disposal of obsolete mobile phones by users/consumers was published during the previous millennium (McLaren et al., 1999). Since 2006, each year at least one research article on this subject has been published and research majority of the research works were undertaken after 2014, mainly due to surge in the generation of obsolete mobile phones. Recycling was the most important aspect that was focused in those studies.

Figure 3 presents the number of articles that focused exclusively on obsolete mobile phones and the location where those studies were conducted (those articles that were cited in this study). It is found that the highest number of research works were undertaken in China. Hence, this indicates that more studies on this area should be undertaken in other countries. Especially in India, Indonesia and the USA as these three countries are ranked after China when it comes to the number of mobile phone users (Cell Phones by Country, 2021). However, those studies, which focused on more than one country were not included in Figure 2. For example, Tanskanen and Butler (2007) focused on the USA and Finland, Geyer and Blass (2010) focused on the USA and UK and Silveira and Chang (2010) focused on the USA and Brazil.

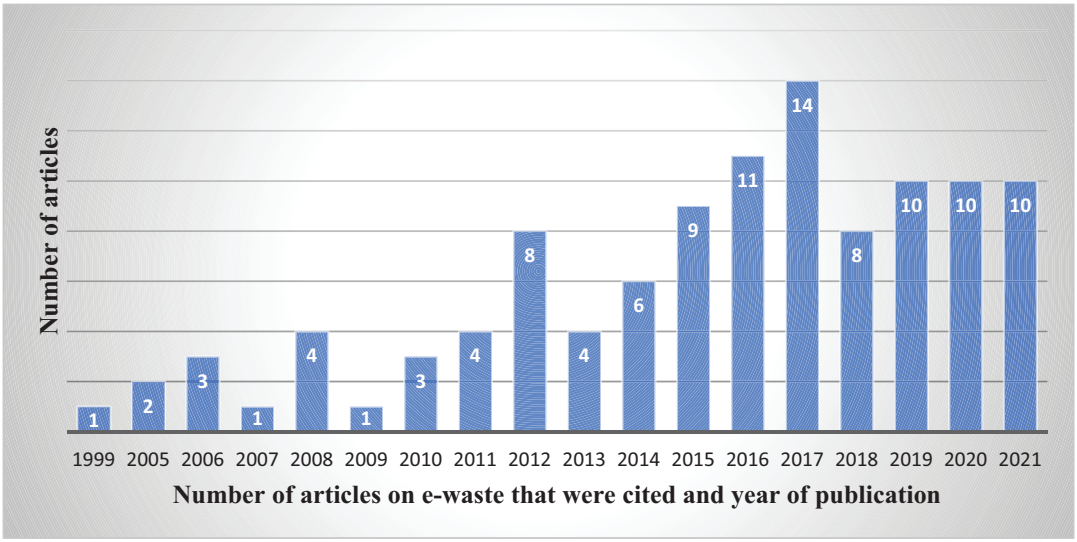

Figure 1. Number of articles on e-waste by year that were reviewed and cited in this study.

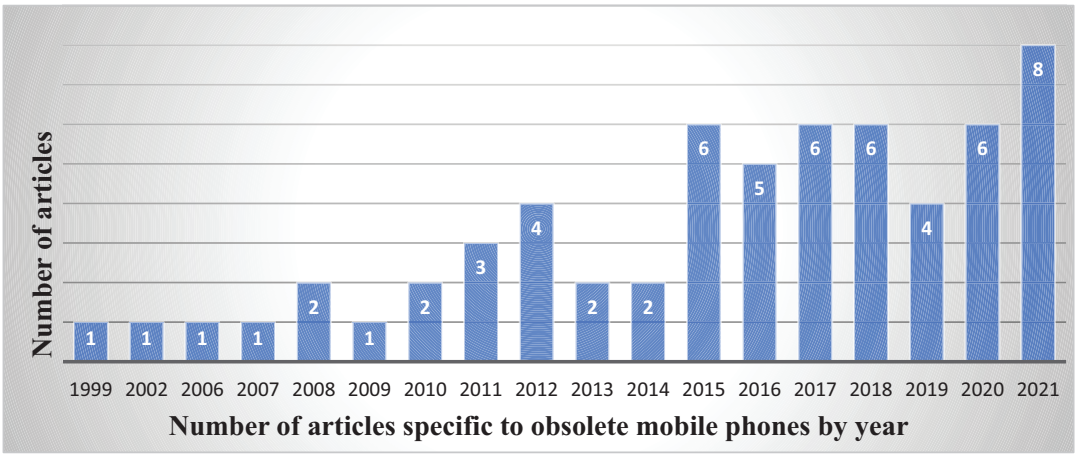

Figure 2. Number of articles by year that focused exclusively on obsolete mobile phones, which were reviewed and cited in this study.

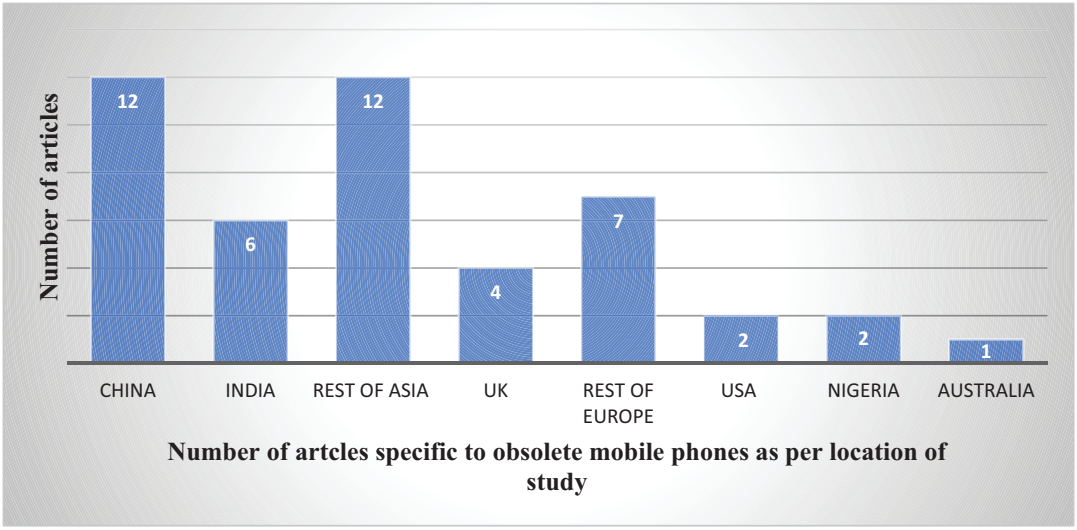

Figure 3. Number of articles that focused exclusively on obsolete mobile phones and the location where the studies were conducted.

Conclusion

This review article focuses on the identification and analysis of various research works undertaken on the disposal of obsolete mobile phones by users/consumers. It also provides broad insights from the various literature taken into consideration for the study. A total of 210 articles that were published in scientific journals, books and proceedings published from 1999 to September 2021 were reviewed. Out of these investigated articles, 109 relevant articles focused on the disposal of electronic devices, including mobile phones, were reviewed and cited in this study. Out of these, 61 articles among those 109 reviewed articles focused exclusively on disposal of obsolete mobile phones.

Various research sub-areas, such as reasons for replacement of mobile phones, disposal methods adopted by the users/consumers, in-use lifespan, reuse and recycling, with regard to the obsolete mobile phones have been identified. The analysis of these sub-topics has helped to identify the main issues that are related to obsolete mobile phones.

Mobile phones are used by many people around the world. Due to reasons, such as mobile phones being damaged, become lesser functional and technological obsolescence, various mobile phones become obsolete and gets replaced. As a result of this, the in-use life span of mobile phones got reduced to between one to two years in many countries. The majority of the users/consumers do not adopt sustainable disposal methods such as handing over to formal end-of-life channels for reuse and recycle. This low adoption of sustainable disposal methods contributes towards difficulties for metal recovery, degradation of the environment as well as human health.

Based on various literature, the authors noted that the findings on various disposal methods adopted and factors affecting behavioural intention to recycle obsolete mobile phones are not the same throughout the studies. It can vary from one geographical location to another as well as changes can happen due to time periods. Although storage post-in-use lifespan is found to be the most opted disposal method, the percentage of users/consumers storing their obsolete mobile phones varies across studies. Storage of obsolete mobile phones and low user/consumer awareness regarding what to do with their obsolete mobile phones are crucial barriers towards reuse and recycling. Reuse leads to the extension of the in-use lifespan of mobile phones and a higher reuse rate reduces the dependency on newly extracted raw materials. However, low willingness to receive second-hand mobile phones, technological obsolescence, low awareness regarding the various disposal methods, storage of obsolete mobile phones, etc. are also barriers to reuse.

The lower proportion of recycling of mobile phones by the formal recycling sector is of very much important concern. From the various studies that focused on recycling, the recommendations, such as the need to increase awareness level even by imparting about recycling in the school education, increasing promotional measures, improvement of take-back systems, incentives to users/consumers for handing over obsolete mobile phones to formal end-of-life channels, instalment of e-waste collection bins at residential areas and public places, proper usage of social media and stronger e-waste related laws, can contribute towards the increase in recycling of mobile phones through the formal recycling sector.

The number of research articles published, specifically on the disposal of obsolete mobile phones by consumers, is lesser when compared to the disposal of waste electrical and electronic equipment (WEEE). But the ongoing trend since 2015 shows that the number of research articles on the disposal of obsolete mobile phones by consumers is getting increased. The scope and interest in research on the disposal of obsolete mobile phones by users/consumers will increase further as a result of growth in consumption, rapid innovation and quicker obsolescence. In the future, the research in unexplored areas of obsolete mobile phones will also happen to develop and implement the sustainable consumption and disposal of mobile phones. The authors believe that most of the relevant research works focused on the disposal of obsolete mobile phones have been discussed in this review article. In addition, this review article can lead to more research in this area as well as more research in under-explored aspects of this area. The insights from this review article can be utilised by various stakeholders such as researchers, mobile phone manufacturers, formal recycling organisations and governments. This in turn will contribute towards the increase of in-use lifespan of mobile phones and sustainable disposal methods as well.

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