E-Waste Recycling Behaviour: A Case Study Of The City Of Johannesburg

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***Abstract*—**This study explores the behaviour of City of Johannesburg (CoJ) residents towards e-waste recycling. The hazard of e-waste has triggered serious concern due to its physical, chemical, and toxic nature, leading to environmental damage and impacting human health. This research investigated the challenges and incentives that can be utilised to encourage pro-recycling attitudes and behaviour in the Information and Communication Technology (ICT) e-waste stream. A mixed-methods approach was used via an online survey and analysed using descriptive statistics and chi-square analysis.

The findings depict that recycling of e-waste is not the first line of disposal. However, increased awareness, accessible WEEE drop-off locations, and positive and negative incentives can motivate consumers to be more responsible for their WEEE, leading to an increase in participation in the recycling of e-waste.

***Keywords*—**e-waste recycling, e-waste recycling behaviour, waste management.

I. Introduction

South Africa only has an e-waste collection rate of 11% as most of it never enters the collection phase of the recycling industry [1]. It is estimated that of this 11% collected, only 9.7% is recycled, leaving 90.3% of the e-waste created unaccounted for [1]. If e-waste ends up in landfills it can result in environmental and human health impacts [2]. Reference [3] shares that only 12.1% of South African respondents know of e-waste drop-off facilities, and 11% correctly disposed of their e-waste through appropriate recycling avenues. The country's e-waste industry is estimated to have a market value of approximately R280 million, but only R38 million is being earned [4]. Reference [5] predicted that e-waste will grow to 6.8 kg per inhabitant on a global scale by 2021. This prediction was made before the COVID-19 pandemic, where a significant shift to internet streaming services and devices, along with the world of work, has changed with large proportions of the global population working from home during strict lockdown measures, and most non-essential workers have continued to work via virtual platforms [6].

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The particularly alarming component of e-waste is that the remaining toxicity of past e-waste that has been landfilled or disposed of illegally is already part of a hazardous cycle contaminating the natural environment, which emphasizes the need to prevent further e-waste contamination [7]. These components of the discussion of e-waste emphasise a drastic need to address the growth and challenges of the e-waste industry because if it remains neglected, the impacts will lead to significant environmental and health effects while missing an opportunity to turn waste into an economic resource. Therefore, this study sought to investigate e-waste streams with specific focus on the ICT stream and e-waste household recycling behaviour in the City of Johannesburg (CoJ) as household consumers play a vital role in the collection and recycling of waste electrical and electronic equipment (WEEE).

II. Background

E-waste is a waste management problem that is being experienced at an international level. Global cities and African cities are finding waste management of WEEE challenging in the 21st century characterised by mass consumerism [8]. Electronic items become obsolete as newer versions are released, increasing the number of electronic items being disposed of [9]. Most of the time, these electronic items are disposed of informally, illegally, or incorrectly, such as through informal incineration of devices [10]. This leads to e-waste becoming a hazardous waste management problem as incorrect disposing leaches toxic components into the environment [11]. This introduction of hazardous e-waste into the environment also provokes human health concerns and can lead to respiratory illnesses, neurological changes, and skin conditions [11]. This e-waste also carries economic value in the single components of these devices that can be returned to their raw state to be recycled and have the potential to be reused while also creating employment through this process [12], [13].

One of the main challenges preventing the e-waste industry from developing is the low volume of e-waste entering the recycling stream [13]. The volume of e-waste that enters the waste stream is significantly influenced by the consumers of electrical and electronic equipment who currently hibernate their devices rather than recycle them [15]. The need to understand consumer behaviour in CoJ households provides the rationale for this research project.

III. Methodology

The study area of this research project was set in the City of Johannesburg and was selected due to it being the economic hub of South Africa and one of the largest local producers of

waste and e-waste. As supported by the South African State of Waste Report [2], Gauteng is currently the core of both the economy, and waste electronic and electrical equipment (WEEE) collection and processing as it works with almost 55% of South Africa's e-waste. However, only an estimated 9.7% of collected e-waste is said to be recycled and recovered [2].

A non-probability-based sample technique, specifically convenience sampling, was used for data collection using the questionnaire survey tool. As specific answers on behaviour and attitudes needed to be answered, non-probability-based sampling allowed a larger population to participate in this research as any interested individual participated in the research by completing the online questionnaire. This sampling technique was also selected due to the limitations of COVID-19 at the time of data collection. With its need for social distancing, the pandemic limited in-person communication, which called for online communication with the target population [16]. A pilot run of the questionnaire was administered online to identify any errors or ambiguities that may affect the questionnaire results' reliability and validity and after a review of the feedback the questionnaire was circulated for data collection. The target population composed of individuals aged 18 and older and living in the CoJ. The study composed of a total of 286 participants who submitted completed questionnaires. The participants were invited via residential associations' social media platforms. It is important to note that this research is applicable to metropolitan areas but not to smaller towns and rural areas where electronic and electrical device usage may differ.

This research was conducted by blending qualitative and quantitative approaches as specific recycling qualities and numerical data were collected. Data collection occurred through questionnaires that included open-ended questions such as additional experiences or challenges the respondents wish to share and closed-ended questions such as preferred e-waste stream collection options and preferred incentives. A total of 286 participants submitted completed questionnaires for analysis. The integration of the approaches provides more confidence in the findings that are collected and interpreted and provides a more varied collection of data to be analysed [17]. While online questionnaires make participation easier and reach larger samples, they do make participation inaccessible to those who do not have devices or internet connection [18]. The questionnaire was designed with statements to determine household recycling behaviour. The statements used were similar to statements in other recycling research, such as the statements used to assess recycling behaviour of solid household waste [19], [20] but have been adapted for e-waste recycling and behaviour in the CoJ. Section A of the questionnaire collected demographic data, Section B focused on WEEE found in households (large and small appliances, ICT items etcetera) and disposal methods while Section C focused on knowledge, intention, and attitudes towards e-recycling. Lastly, Section D focused on recommendations for recycling e-waste.

Once the data was collected, quantitative and qualitative analysis of the results was conducted. Statistical analysis was selected for both descriptive and inferential statistics. For the questions using a Likert scale of agreement, answering the first two objectives (determining household recycling behaviour concerning the ICT e-waste stream and identifying challenges and incentives influencing household e-waste recycling behaviour), descriptive statistics have been used to analyse these results to determine an average response. For open-ended question results yielding qualitative data, content analysis, more specifically, thematic analysis, was used to identify the frequency of common keywords and themes present in the data collected. For the third objective of investigating the relationship between e-waste recycling behaviour and the demographic variables of income level and age, a chi-square test for independence was conducted to identify if there was a significant relationship between demographic variables and prior e-waste recycling behaviour. A chi-square analysis tells us the depth of correlation between two variables and their association [21].

IV. Results and Discussion

This section will discuss the results of the study and follows key areas of the questionnaire. This discussion will begin with e-waste recycling knowledge and participation by CoJ residents, followed by the perceived economic and environmental concern associated with e-waste and recycling of it, the challenges limiting e-waste recycling behaviour and accompanied suggestions to address these challenges, and will end with the discussion of the relationship between the demographic factors of income level and age and e-waste recycling behaviour.

A. Demographics

The 286 participants reside in a range of suburbs located in the CoJ with a high proportion of 40 individuals from Modderfontein, 26 from Lonehill, 24 from Boskruin, 17 from Greenside and the remainder from other suburbs. In terms of the gender demographics, 69.4% of respondents identified as female, 29.9% identified as male and 0.7% identified as LGBTQIA+ which overall shows a higher participation from females. The average mean participant age was 50 years. Demographics on education showed that 1.8% of respondents had some high school education, 13.7% have their National Senior Certificate (matric), 23.2% have a post-matric diploma or certificate, 20% have a bachelor's degree, and 41.4% have a post-graduate degree (honours, master's or doctorate) which reflected a high proportion of participants possessing a tertiary level of education. For household monthly income, 0.7% stated that their household income was less than R3 500 per month while 38.1% stated it was more than R75 000 per month reflecting a higher participation from those with higher household income.

B. E-waste recycling knowledge and participation

The e-waste recycling knowledge and participation of residents in the CoJ were established by analysing the average agreement levels towards statements provided in the questionnaire. Only

54.4% of participants shared that they know or have heard of e-waste recycling projects in their area in the CoJ while 45.6% said they have not. In terms of prior recycling participation, 57.7% shared that they have recycled their e-waste in the past, while 42.3% stated that they have not previously recycled their e-waste. When asked whether respondents recycle their e-waste or not, just over half of the sampled population said they recycle their e-waste based on previous recycling activity but there is still a need for more residents to participate in the recycling of their e-waste. The potential of e-recycling behaviour increased to 82.2% when asked if they plan to recycle their e-waste in the future. This shows an increase in a more pro-environmental attitude and increased willingness to start recycling their e-waste for all WEEE streams.

Three statements investigated respondents perceived control in e-waste recycling (Fig. 1). Overall, respondents indicated that they do not have much control in e-waste recycling activities. The most positive response was for the statement 'I know how to recycle my e-waste' where 43.5% of respondents agreed or strongly agreed with this statement. The second statement for perceived control was 'E-waste recycling is easy' where 25.4% of respondents agreed or strongly agreed with the statement, and 45.2% disagreed or strongly disagreed with the statement. Thus, the majority of respondents did not find recycling of their e-waste easy. The third statement was 'I have plenty of opportunities to recycle my e-waste' where only 18.7% shared that they agreed or strongly agreed with this statement. In contrast, 55.7 % disagreed or strongly disagreed with this statement. These responses emphasize the significant gap in the provision of e-waste recycling opportunities to make e-recycling of all streams more accessible for households in the CoJ. Perceived control has been witnessed to be much higher for solid waste as seen in solid-waste research than it is for e-waste. In comparison, a recent study shared the following perceived control for solid waste [22]. First, 63% of respondents indicated that they know how to recycle their waste [22]. Second, 55.1% agreed or strongly agreed that recycling is easy while 26% disagreed or strongly disagreed with it being easy [22]. Last, 61.4% agreed or strongly agreed that they have plenty of recycling activities, while 20.8% disagreed [22]. This shows that there is an overall higher perceived control in solid waste activities than there is in e-waste recycling activities.

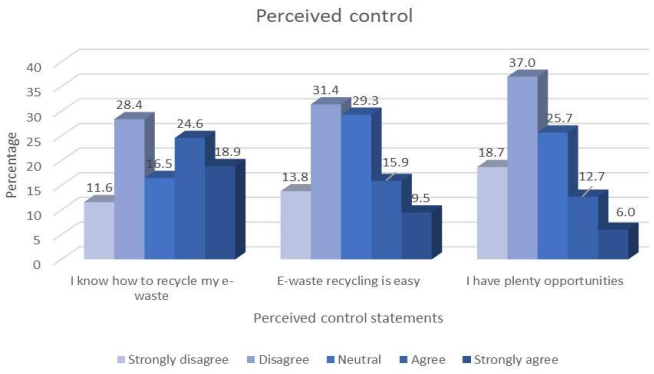

Fig. 1 Perceived control regarding e-waste recycling

C. Perceived economic and environmental concern

Overall perceptions from the participants' responses show acknowledgement of the economic value associated with e-waste recycling. In response to the statement 'E-waste items include valuable materials', 87.7% respondents agreed or strongly agreed whereas 1.1% disagreed or strongly disagreed and 11.3% had a neutral stance (Fig 2.). This was supported by the accompanying statement, 'Recycling my e-waste creates jobs', to which 82.8% agreed or strongly agreed to this benefit of e-waste recycling. In contrast, 0.7% of respondents disagreed and 16.5% were neutral to this statement. Thus, it can be said that CoJ households acknowledge the economic importance of developing the e-waste industry.

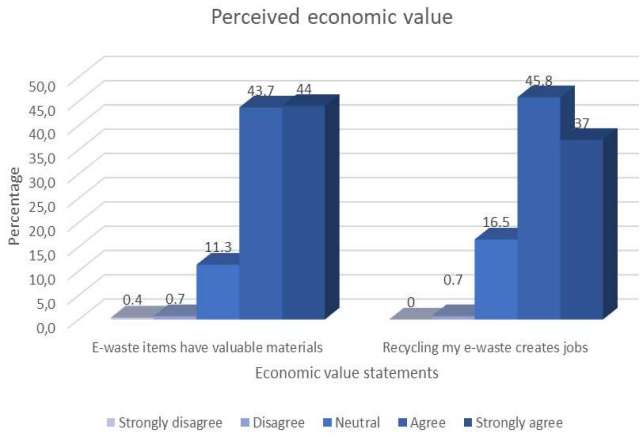

Fig. 2 Perceived economic value of e-waste recycling

In terms of the environmental value of e-waste recycling, there was a clear acknowledgment of the role of e-waste recycling in reducing damage to the environment. In response to the statement, 'E-waste recycling reduces damage to the environment', 90.6% agreed or strongly agreed whereas 3.9% disagreed or strongly disagreed and 5.6% were neutral (Fig. 3). For the statement 'It would be wrong of me to not recycle my e-waste', 87% agreed or strongly agreed while 3.5% disagreed or strongly agreed and 9.5% were neutral. In response to the statement 'E-waste recycling is the responsible thing to do', 96.1% of participants agreed or strongly agreed while 1.1% disagreed or strongly disagreed and 2.8% held a neutral stance. These statistics reflect an overall positive attitude held by CoJ households towards e-waste recycling as they acknowledge the importance that e-waste has in preventing environmental destruction, and that partial responsibility of correctly recycling e-waste falls to residents. While consumers' attitude is essential to understand the state of e-waste recycling in the CoJ, it is vital to also look at the actual e-waste recycling practices.

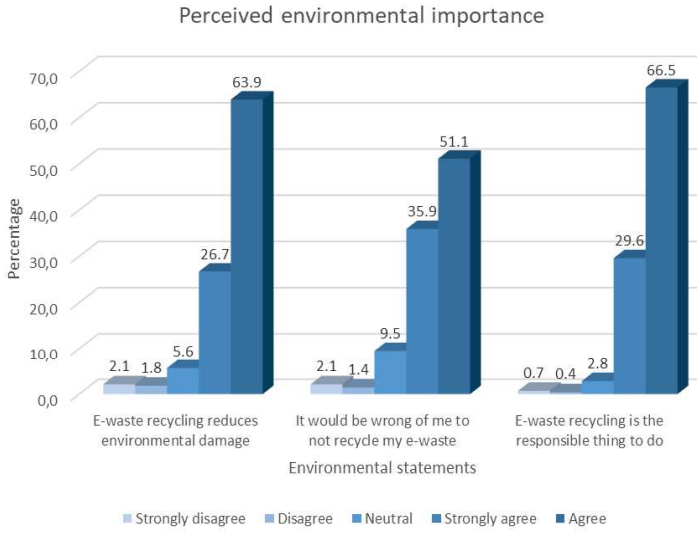

Fig. 3 Perceived environmental value of e-waste recycling

D. Challenges limiting current e-waste recycling

The second objective of the study focused on identifying factors influencing household e-waste recycling behaviour. This objective was answered in two ways; first, through agreement levels of statements via the Likert scale and secondly, the last open-ended question in the questionnaire allowed for keywords to identify these challenges. A general challenge shared by respondents was a lack of education and accessibility as information needs to be shared on what e-waste recycling is, how and why it should be done, and where it can be done. These comments were further supported by 12.1% of respondents who strongly agreed, and 21.6% who agreed that recycling e-waste is too complicated (Fig. 4). The thematic analysis identified that keywords such as 'accessibility,' 'drop-off points,' and 'convenient locations' were mentioned by 29% of respondents. Additionally, keywords of 'information,' 'education,' and 'awareness' were mentioned. More specifically, 29% of respondents shared that accessibility in terms of convenient drop-off points needs to be prioritized. Safety and security of old data was also a concern for some respondents when dealing with ICT WEEE, which emphasizes the need for e-waste recycling companies to improve awareness and implementation of data erasure certificates as certificates are usually only provided on request to promote the Protection of Personal Information Act [23].

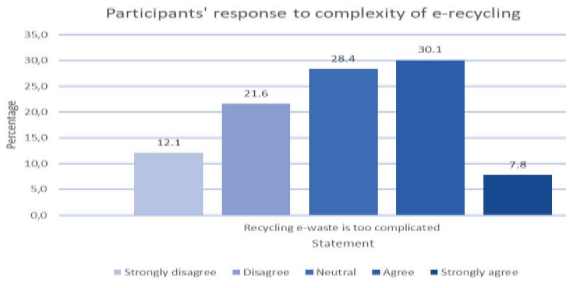

Fig. 4 Participants' response to complexity of recycling e-waste

This general lack of knowledge and accessibility only furthers consumers' apprehension towards e-waste recycling. Many resources exist online to help consumers recycle their waste electrical or electronic equipment (WEEE) correctly; however, more visible marketing is required to make these resources known. Inaccessibility is supported as a challenge as 18.7% of participants strongly disagreed, and 37% disagreed that there are plenty of opportunities to recycle their e-waste. This highlights the need to increase the number of accessible drop-off zones for e-waste and community e-waste recycling initiatives to assist and encourage households. A few participants in the study stated that while they used to deliver their e-waste to a drop-off centre in the past, those locations have since closed, and most website information on recycling centres that accept WEEE of different streams are outdated. This calls for the need to update traditional marketing, websites, and other online advertisements that share information on where consumers can recycle. The following quote from a respondent shares this sentiment:

"Need information available online in an SA context. I tried to recycle a vacuum cleaner some years ago. Took it back to Samsung at Cresta, but it had closed. None of the other stores would accept it for recycling. I left it on the street in the end, and waste pickers collected it. I put small items (broken GPS and hand blenders) in recycling bags and always hope it's okay that I do so. I do drop items off at a recycling facility in Parkhurst, but I sometimes don't know if I am putting things in the right place".

E. Suggestions to increase the recycling of e-waste

Common keywords that arose when participants were asked what could be done to increase e-recycling practices, common keywords were 'accessibility,' 'organization,' 'education' and 'awareness,' 'incentives,' 'training,' and 'drop-off sites'. Education at both a community level and in the South African schooling system, was promoted as necessary to understand what WEEE of different streams are composed of, why and how it should be correctly disposed. Almost a third of respondents (29%) shared that accessibility in terms of convenient drop-off points needs to be prioritized. Furthermore, respondents stated that drop-off zones within popular shopping centres would help increase the ease of recycling their e-waste for smaller and medium sized items while collection is needed for larger items that are difficult to transport. Incentives were mentioned often to motivate consumers to recycle their e-waste. Positive reinforcement includes rebates on purchased EEE and discounts on devices when returned for recycling. This positive reinforcement aligns with the incentives promoted in other studies [24], [25], [26]. The findings from this study reveal that direct financial incentives are not the first choice of incentives but rather donations in their name towards environmental and community causes were favoured, with 81.1% and 81.7% respectively strongly agreeing and agreeing that this would motivate them to recycle their e-waste in comparison to 67.5% collectively agreeing that financial incentives would encourage them. However, the financial sources to fund such an initiative

are a challenge to implement, particularly in the socio-economic climate of Johannesburg where other priorities exist. In contrast, there were negative reinforcement suggestions by two participants who stated that more intense legislation, penalties such as fines, and government monitoring need to be adopted to urge CoJ residents to be more responsible with their WEEE. Such strengthening of recycling legislation is supported by other recycling studies [27], [25].

F. The relationship between income level and e-waste recycling behaviour

The null hypothesis set for the chi-square analysis to test the significance between income level and e-waste recycling behaviour was, 'E-waste recycling behaviour does not depend on the income level of consumers.' After cross-tabulation of income level and whether respondents had recycled e-waste previously, using chi-square analysis, the p-value was compared with the α value as suggested by [21]. It should be noted that zero cells had an expected count of less than five, so the chi-square assumption of independence is valid. This allowed for testing of the significance present between income level and e-waste recycling behaviour. The test result of the Pearson chi-square p-value of 0.221 is larger than the α-value of 0.05, which results in the upholding of the null hypothesis (TABLE I). The results reflect that income is not a significant demographic variable that influences households recycling their e-waste. In contrast, some studies have identified a correlation between household income and e-waste recycling behaviour with the justification that higher-income households ought to find recycling more accessible as they can afford to travel to recycling drop-off centres or pay courier fees [28]. This study shows that while higher-income receiving consumers afforded more expensive EEE such as Google Home Systems, it did not influence the participants' e-waste recycling behaviour any more than the recycling behaviour of other income-earning households.

TABLE I

CHI-SQUARE ANALYSIS OUTPUT FOR CROSS-TABULATION BETWEEN HOUSEHOLD INCOME AND PREVIOUS E-WASTE RECYCLING PRACTICES

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.404[a]	3	0,221
Likelihood Ratio	4,387	3	0,223
Linear-by-Linear Association	4,327	1	0,038
N of Valid Cases	273		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 17.85.

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	0,127	0,221
	Cramer's V	0,127	0,221
N of Valid Cases		273	

G. The relationship between age and e-waste recycling behaviour

To test the relationship between age and e-waste recycling behaviour, the null hypothesis set was, 'E-waste recycling behaviour does not depend on the age of consumers.' After cross-tabulation of the demographic variables of age and past e-waste recycling behaviour, using chi-square analysis, the α-value and p-value were compared to determine if there was a significant relationship or not. The chi-square assumption of independence was valid during this test as zero cells had an expected count less than five. The p-value was 0.002 and therefore smaller than the α-value of 0.05. Thus, the null hypothesis was rejected and can be reformulated to state that 'E-waste recycling behaviour is dependent on the age of consumers' (TABLE II). Thus, the results reveal that age is a significant demographic variable for influencing recycling behaviour as a higher proportion of middle-aged participants have previously recycled their e-waste. In contrast, there were lower proportions of younger and older aged participants having previously recycled WEEE as discussed in other studies [19], [24]. The results of this study on e-waste recycling behaviour in the CoJ better align with a study conducted on household recycling and millennials also based in the CoJ [20]. In contrast to popular beliefs, Johannesburg millennials are not as knowledgeable about recycling as previously expected or actively practice recycling, which has been accompanied by diminished marketing programmes to raise awareness of the importance of recycling and the necessary resources provided to residents (20).

TABLE II

CHI-SQUARE ANALYSIS OUTPUT FOR CROSS-TABULATION BETWEEN AGE AND PREVIOUS E-WASTE RECYCLING PRACTICES

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	19.040[a]	5	0,002
Likelihood Ratio	19,247	5	0,002
Linear-by-Linear Association	6,676	1	0,010
N of Valid Cases	281		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 8.89.

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	0,260	0,002
	Cramer's V	0,260	0,002
N of Valid Cases		281	

V. CONCLUSION

Electronic consumption is being further pressured by the Fourth Industrial Revolution, which calls for increased use of the Internet of Things and technology to replace traditional means of doing things leading to growing e-waste [18]. This study has aimed to investigate e-waste recycling behaviour of households in the City of Johannesburg. The main challenges

identified were a lack of knowledge, lack of time, accessibility issues, and outdated e-waste recycling information. This has resulted in the need to update information resources, provide awareness and education programmes on how, why, and where to recycling e-waste. The findings from this research reflect that respondents have an overall positive recycling attitude and acknowledge both the environmental and economic value inherent in recycling e-waste. This was supported by a majority of respondents who agreed or strongly agreed that WEEE contains valuable materials and creates job opportunities. Suggestions of using positive and negative reinforcement have been identified to encourage the adoption of e-waste recycling practices. Overall, it can be concluded that despite the increasing production of e-waste in South Africa that is estimated per annum to be 7.1 kg generated per person, recycling of e-waste is still not taking place at the rate that is aimed to streamline a more sustainable state of waste [12]. Changes need to be made to the e-waste industry, and programmes to engage CoJ residents and encourage more positive e-waste recycling behaviour must be established. Ultimately, the growing e-waste industry presents both challenges and opportunities in the state of waste management, but further research is required to understand its presence and management.

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