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Exploring the factors influencing consumer behaviours and practices towards sustainable WEEE management in Putrajaya, Malaysia

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ABSTRACT

The disposal practises and preferences of household waste from electrical and electronic equipment disposal (WEEE) are essential components in material flow analysis (MFA). Nevertheless, the synergistic of consumers' behaviours and preferences with the disposal of different WEEE has yet to be investigated in depth. This study examined several consumer features of WEEE management using a quantitative questionnaire survey, including consumers' disposal behaviours and preferences. As a Malaysian federal government administrative centre, and model of a contemporary and sustainable Malaysian city, Putrajaya was chosen as the study area. Using stratified random sampling, the questionnaire was distributed through face-to-face and online surveys among households across 20 precincts within Putrajaya. From June 2021 to January 2022, 500 surveys were distributed over seven months, and IBM SPSS Statistic version 26 was used to analyse the data. The result shows that 80% of respondents have a good knowledge of WEEE management and are fully aware of the dangerous materials they have in their WEEE. 75% said they would recycle their WEEE, but only 44% said they would separate it from other household wastes. It was also shown that 88% of the household were willing to pay a collection fee of at least RM 10 for each collection. This analysis found that Extended Producer Responsibility (EPR) mechanisms can assist in overcoming weaknesses in WEEE management by including beneficial schemes to incentivise consumers to improve current waste policies. In the meantime, governments, media, and local non-governmental organisations may help by increasing awareness of effective and sustainable WEEE management.

1. Introduction

Waste electrical and electronic equipment (WEEE) has become a serious global issue as a result of the increased use of electrical and

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electronic equipment (EEE) as a result of fast improvements in information and communication technology. With an average of 7.6 kg of e-waste generated per person in 2021 and improper disposal practices, WEEE has become a severe environmental and health threat [1]. Addressing challenges such as consumer behaviour, knowledge, and awareness, as well as improving WEEE collection and recycling methods, is critical for efficient WEEE management. Consumer participation and knowledge distribution are critical components of attaining sustainable production and consumption [2–5].

To enhance recycling rates, consumers must be effectively informed about their participation in the entire reverse supply chain, since they play a critical role in attaining sustainable production and consumption [6–10]. Consumer behaviour is recognised as a crucial aspect of sustainable production and consumption by the United Nations Sustainable Development Goals 12. Improving consumer understanding and awareness of WEEE, as well as involving them in recycling programmes, might therefore contribute to a higher recycling rate [11]. The WEEE management that is effective must account for all three aspects of sustainability economic, social and environmental consequences [12]. Improper disposal practices, such as open burning, dumping with municipal solid waste, or informal recycling activities, offer substantial environmental challenges, particularly in large growing markets such as Asia and Africa. It is difficult to recover effective and efficient WEEE management while accounting for social costs and environmental consequences, yet it is critical to safeguard human health and the living environment [13–15].

Managing WEEE is a challenging issue affecting not just Malaysia but other countries. In Malaysia, the minimal enforcement of current WEEE rules and regulations, as well as the absence of systematic WEEE collection [16]. Several Malaysian researchers have carried out studies to better understand consumer behaviour, knowledge, awareness, habits, and preferences about WEEE. However, some of these studies concentrated on specific items or sources of WEEE, while others overlooked the link to material flow analysis. As a result, more detailed study is required to find the optimal technique for managing e-waste [17–20].

For example [21], studied the youth's intentions to dispose of portable WEEE with proper disposal behaviour in Malaysia by focusing only on knowledge, awareness, and disposal without adequately addressing the connection towards material flow analysis [18]. studied the benefit of WEEE recycling without discussing the characteristics of consumer behaviour. The previous studies can be more comprehensive by investigating other characteristics, such as consumer knowledge and behaviour about WEEE recycling. Some of their studies focused on a single product, such as a mobile phone or television, or many products from the same source, such as WEEE from households, businesses, or institutions.

Taking Malaysia as a case study, the goal of this research is to investigate the consumer behaviour variables that may impact WEEE disposal using a series of quantitative questionnaires. The primary hypothesis is that increasing consumer understanding and awareness of WEEE, as well as involving them in recycling programmes, will result in a greater recycling rate. The research will concentrate on addressing issues such as consumer behaviour, knowledge, and awareness, as well as enhancing WEEE collection and recycling systems, which are essential for effective WEEE management. This study will include variable such as socioeconomic status, knowledge and awareness of WEEE management, WEEE disposal behaviours and preferences. The purpose is to assess EEE consumer readiness and perspective on acceptance for more sustainable WEEE management by determining how these variables impact WEEE disposal in Malaysia.

Malaysia was chosen as the study's primary focus to reflect the current condition of WEEE management in the Global South region since the majority of WEEE is generated in Asia. This study's methodology can be used as an example for other countries to follow. The findings of this study will help to develop effective strategies for promoting sustainable WEEE management, reducing environmental and health risks associated with improper WEEE disposal, and achieving UN Sustainable Development Goal 12 of sustainable production and consumption.

2. The development of WEEE management

2.1. World scenario of WEEE management

The WEEE is expected to reach 74 million tonnes (Mt) by 2030, making it the most prevalent type of waste. In 2019, Asia generated the most WEEE with 24.9 Mt, followed by America with 13.1 Mt, Europe with 12 Mt, Africa with 2.9 Mt, and Oceania with 0.7 Mt. Despite the fast rise of WEEE, recycling rates are not improving in lockstep with this type of waste. Globally, Europe recycled around 42.5% of its waste in 2019, followed by Asia at 11.7%, America at 9.4%, Oceania at 8.8%, and Africa at 0.9% [22].

The rising consumption of EEE is substantially influenced by the industrialization of technology and the increased affluence of the world's population [23]. Due to the evolution of technology, EEE has increasingly shorter life cycles due to technological advances, which, together with few repair options for these products, generate an increase in e-waste. The increased demand for EEE in various sectors, including households, has raised concerns about WEEE, which can pose environmental and human health dangers [24–27]. Toxic and hazardous compounds may be present in EEE and cause pollution if not properly disposed of or controlled. However, when WEEE is handled properly, the metals or resources are worth roughly USD 65 billion, which is similar to the GDP of most nations [10].

Thus, proper WEEE management has sparked the interest of policymakers and the corporate environment as an alternative source of resources, given the surging shortage of natural resources. However, the most highlighted concern in WEEE management is the absence of infrastructure for efficient WEEE management in developing countries [28–30]. Developed countries, on the other hand, generally have stricter WEEE regulations than developing countries, which have inadequate WEEE legislation and infrastructure, allowing illicit and informal trade [31–33]. It led to the growth of the informal sector, with no regulation and little protection, inflicting significant harm to the environment and the health of personnel.

International WEEE policies and regulations are critical because they give players in the government and industries dealing with WEEE with a set of rules and instructions. The Basel Convention, established in 1992, restricts the transport of rubbish deemed

environmentally and socially hazardous, including electronic waste [34]. It significantly regulates hazardous waste commerce and reduces unlawful transportation. WEEE Act controls the parties' responsibilities and operations. Most developed nations, such as Switzerland, now have the most extensive WEEE law and regulations, followed by most countries in America and Asia (east and south) [31,32,35]. Meanwhile, most African, and Asian (Central Asian) countries lack national WEEE laws and regulations. Most legislations are based on the Extended Producer Responsibility (EPR) principle, which holds manufacturers and importers accountable for the whole product life cycle, including end-of-life management [12,20,25,36,37]. Table 1 compares the implementation of WEEE management mechanisms in the world's developed and developing economies.

2.2. Malaysia's perspective on WEEE management

2.2.1. Legislation and implementation

Malaysia has taken significant steps to manage WEEE through the Department of Environment (DOE) with Environmental Quality (Scheduled Waste) Regulation 2005, which classifies e-waste as scheduled waste. The rule empowers Malaysian authorities to regulate the transboundary movement of e-waste. This WEEE is divided into 77 categories, with WEEE classified as follows:

- SW103 (Waste of batteries containing cadmium, nickel, mercury, or lithium),
- SW109 (Waste containing mercury and its compound),
- SW110 (Waste from electrical and electronic assemblies containing components such as accumulators, mercury-switches, glass from cathode-ray tubes and other activated glass, or polychlorinated biphenyl-capacitors, or contaminated with cadmium, mercury, lead, nickel)

Since Malaysia is a signatory to the Basel Convention, WEEE cannot be imported without prior written permission [17]. In 2008, the DOE produced the Guidelines for the Classification of Used Electrical and Electronic Equipment, which defined the features and components of e-waste to assist waste generators, importers and exporters, and relevant agencies in distinguishing between WEEE and non-e-waste [14,38]. In response to increased concern about the environmental threats presented by WEEE, the Malaysian government is working on a new regulation governing household electrical and electronic waste.

As part of the 12th Malaysia Plan (12MP), the law would contain the EPR concept. Producers are held accountable for the treatment and disposal of post-consumer items under the EPR strategy [12,38–41]. The EPR strategy will be expanded to include more waste kinds and streams, and waste separation at the source will be enforced to promote reducing, reusing, and recycling (3R) operations [20,36,37,42]. This technique will increase the efficacy of waste management, and a complete database for all sorts of waste will be built to monitor and support circular economy activities.

In addition to the EPR approach, a range of integrated waste management facilities will be established, including a material recovery facility to sort and segregate waste, a treatment facility containing an anaerobic digester, composter, and incinerator, and a sanitary landfill [19,39,43]. The implementation of these facilities will further enhance the waste management system in Malaysia and promote sustainable waste management practices.

2.2.2. Challenges of WEEE management in Malaysia

Malaysia is facing challenges in managing WEEE in an environmentally sound manner (ESM). The government is striving to control the level of household e-waste while simultaneously implementing a long-term management system [44]. WEEE management is a

Table 1
Implementation of WEEE management mechanisms in the World's developed and developing economies.

Status	Country	Legislative and policy	Year of Enforcement	Responsibility
Developed	European Union (All 27 member states)	EU Directive 2012/19/EU on WEEE Management	2012	Producers, members of the states, and distributors
	Australia	National Waste Policy Action Plan	2009	Federal, State, and Local Government
		Product Stewardship (Televisions and Computers) Regulations National Television and Computer Recycling Scheme	2011	Industry and government
	America	Resource Conservation and Recovery Act (RCRA)	1976	Environmental Protection
		National E-Waste Management Initiative	2018	Agency (EPA)
Developing	China	Administrative measures on the pollution control caused by electronic information products (Often referred to as Chinese RoHS)	2006	Manufacturer
		Regulation on the Control of Pollution Caused by Electronic Information Products	2011	Producer and government
	Taiwan	Resource Recycling Act	1998	Producers and government
		Waste Disposal Act and Regulations Governing Recycling and Disposal of Electrical and Electronic Equipment	2000/2002	
	Indonesia	Government Regulation on Hazardous and Toxic Waste Management	2011	Producers and government
		National E-Waste Management Plan	2018	

worldwide challenge since it includes cross-border mobility across all nations and territories, and huge volumes of WEEE are shipped to poor countries for reuse, refurbishment, recycling, and precious material recovery [38,44–46]. Malaysia like other developing countries has become attractive destinations for WEEE from wealthy countries, with the majority of it managed in an unsustainable manner, resulting in serious environmental and health effects [15,35,39].

Although the DOE has gathered a substantial amount of e-waste, the government still faces challenges in efficiently managing it. As shown in Fig. 1, the DOE collected a large amount of WEEE in 2021, with the majority coming from the industrial and commercial sectors. Household e-waste, on the other hand, adds considerably to Malaysia's total amount of WEEE generated [34]. According to the DOE statistics, 2459 tonnes of household e-waste were collected in 2021, demonstrating that Malaysian houses generate a substantial quantity of e-waste [12,47,48].

Aside from the growing number of e-waste generated, the illicit e-waste streams from both the formal and informal sectors are a major source of concern in Malaysia [35,49]. The informal sector inefficiently handles e-waste, resulting in inefficient procedures and adverse environmental and health implications. Meanwhile, the formal sector is struggling to pay collection fees and the expensive cost of treatment, resulting in ineffective management [17,19,39,50]. The system for collecting and handling e-waste is still in its infancy. Additionally, initiatives made by the government and authorised organisations are poorly organised and have a restricted reach.

Presently no mechanism is in place to encourage the general public to recycle and dispose of their e-waste through proper segregation or disposal methods [20]. The accumulation of e-waste over time, along with a lack of defined institutional framework processes and inadequate infrastructure, results in poor e-waste management [13,15,38]. Although Malaysia has established legislation and standards for e-waste management, these guidelines only differentiate between e-waste and non-waste and outline the requirements for importing and exporting old EEE or components that are not categorised as e-waste [16,20]. There is no guidance on how Malaysian consumer should handle their e-waste once the product's lifespan has ended. These standards may have helped EEE consumers discern which goods qualify as e-waste and which do not. However, the laws may allow the government to improve e-waste reuse and recycling.

3. Consumer behaviour in WEEE management

WEEE can significantly impact the consumer in two ways: when obsolete equipment must be replaced and when the equipment is discarded [51]. Meanwhile, consumers in the WEEE can be divided into two groups: those who are EEE users and those who are WEEE disposers. Both represent a middle phase of the product life cycle, namely the usage phase and an intermediate phase between other stakeholders, the manufacturer and recycler. Both roles are critical in resolving the WEEE problem. According to Ref. [3] consumer behaviour is an essential psychological attitude toward cyclical behaviours. Cultural, educational, and communication variables significantly influence population behaviour toward adopting the circular economy at all levels [3,32,52–54].

Cultural characteristics are the first major component of consumer behaviour. It is motivated by cultural ideals. As humans, consumers are impacted by their surroundings and cultural norms. Consumer behaviour varies according to ethnicity and society, and even attitudes regarding buying culture or WEEE management and disposal behaviour. According to Ref. [52] consumer ethics and culture have even influenced how people use products throughout their lifetimes and how they extend their usage through 3R.

Education has a direct effect on consumer behaviour and attitude. Education is related to knowledge connected to awareness, affecting the consumers' perception and attitude toward the environment and other social causes [2,55,56]. With education, consumers become more concerned about the welfare of the ecology with consumer behaviour. Psychographic profiling, also known as the study of personality, values, attitudes, and lifestyles, has shown that conscious consumer behaviour towards ecology is dynamically related to their level of education [57]. Knowledge acquired also involves what they buy and how they perceive the value.

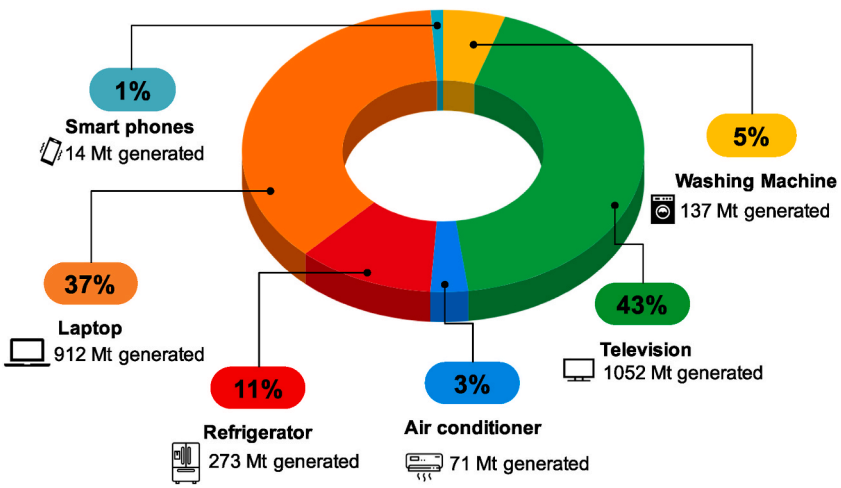


Fig. 1. WEEE collected by the Department of Environment, Malaysia, in 2021.

Communication has a tremendous impact on consumer behaviour. Proper and effective communication about a cause and its consequences may influence behaviour, whether a brand or a social cause [58]. Effective marketing, promotion, and so forth can influence consumer behaviour. As social media has grown in popularity, it has become a powerful tool for influencing consumer, social behaviour and attitudes [2,32,59]. In the context of WEEE management, good promotional campaigns, or programmes (3R, take back, VIVO ERTH, etc.) may entice consumers to participate in the programmes.

Table S1 in supporting information summarises previous consumer behaviour-related studies in WEEE management. A total of 17 analysis papers were selected for careful consideration. In summary, these authors looked at various areas, such as consumers' general knowledge and awareness, WEEE disposal practices, and recycling preferences. Although other factors, such as consumption, storage, and willingness to pay (WTP), are included, the customer's readiness for sustainable WEEE management and other disposal preferences to observe the WEEE stream after the user has disposed of their e-waste is not considered. Hence, the questionnaire analysis in this study incorporates the missing criteria to enable new policy suggestions and a more quantitative approach to improving data quality.

4. Methodology

A series of quantitative questionnaires were distributed to Putrajaya households to better understand consumer behaviour and preferences in WEEE management and reflect on its significance as a sustainable model city in Malaysia. The study results will serve as a baseline for implementing sustainable WEEE management in Malaysia's urban and suburban areas.

4.1. Study area

The research site includes EEE consumers in the community residing in Putrajaya, located 25 km south of Kuala Lumpur, which covers an area of 4,931 ha. Putrajaya, the federal state, has a total of 20 precincts. The study was designed at Putrajaya to reflect the Federal Government Administrative Centre and Malaysia's Diplomatic Hub, as well as Putrajaya's role as a model sustainable city in Malaysia.

According to the Department of Statistics Malaysia (DOSM), Putrajaya's population will reach 0.12 M in 2021, with a 5.4% average population growth rate. Putrajaya is the state in Malaysia that contributes the most (7.5%) to the country's gross domestic product

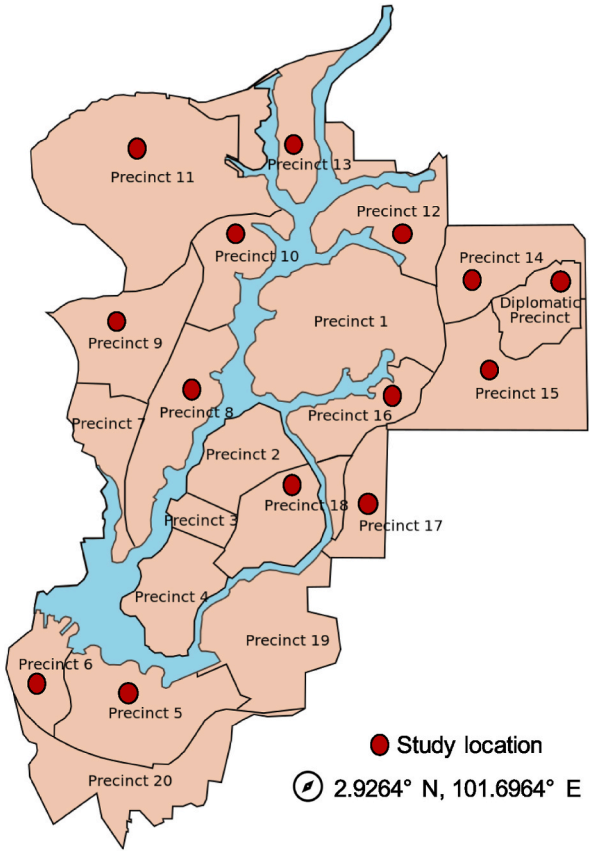


Fig. 2. Map of Putrajaya.

(GDP) performance. Putrajaya residents' mean monthly income and wages (RM 4,497) surpassed the national mean monthly salaries, which ranged from RM 2,933 to RM 3,224. Aside from the factors mentioned above, Putrajaya has been designated as the model pilot state for the success of the national strategy toward sustainable living. Currently, Putrajaya is on its way to becoming a model green metropolis (Putrajaya Green City 2025) in Malaysia, with a commitment to establish the pillar of sustainability in preserving economic, environmental, and social balance.

Putrajaya maps are shown in Fig. 2. Although Putrajaya has a total of 20 Precincts, only 13 Precincts were chosen as the study location due to the presence of a residential area. Precincts 1–4 were governmental offices, whereas Precinct 7 was a restricted area for service centres such as health facilities, police and firefighter stations, and park and ride stations (MRT and ERL- Putrajaya Lane). Meanwhile, Precincts 19 and 20 were designated as recreation and wetland areas.

4.1.1. Socioeconomic of the respondents

Of the 500 respondents, 72.6% were female, and 27.4% were male. With average group between 15 and 24 years old was 66.0%. The majority of the respondent was bachelor's degree holder (55.8%) and were employed (60.8%) either in the governmental or private sector with an average income of RM 2,000 to RM 4,000 (21.2%). This shows that the education status of the society in the area of study is comparatively high, which is potentially linked to the area's higher economic standing compared to other Malaysian states. Since Putrajaya is the government sector's hub, most respondents (42.4%) lived in government quarters, with the majority residing in landed houses (53.2%). When asked if they had waste collected by a waste operator, 81.0% responded yes, and the waste operator came to their residence to collect waste. Details regarding the socio-demographic characteristics of the participants are given in Table S2 in supporting information. The table also provides the demographic's average mean and standard deviation (sd) to indicate how much variance there is from the average (mean). A low sd implies that the data points are close to the mean, whereas a high sd suggests that the data are dispersed throughout a wide range of values.

4.2. Questionnaire design

The primary data was obtained through a questionnaire survey. The questionnaire is divided into five sections: i) determines the respondent's demographics, ii) evaluates the respondent's ownership of WEEE, iii) examines the respondent's knowledge and awareness of WEEE management, iv) determines the respondent's practise and preferences regarding WEEE, and v) determines the respondent's attitude of WEEE management of the respondent. The questionnaire design can serve as a baseline reference for future studies on consumer behaviour characteristics in sustainable WEEE management in other countries. As the questionnaire does not include any personal information details, it does not require ethical approval from any organization. The questionnaire can be found in the supporting information document (Appendix A).

4.2.1. Sampling methods

In this questionnaire study, simple random sampling was performed. At random, a small group of people or members of a larger population was chosen. It assures that each individual or population member has an equal and fair opportunity of getting chosen. Putrajaya's population is predicted to be 0.12 M in 2022. To select a random sample of this population, we used the following formula in our study.

$$ss' = \frac{z^2[P-(1-P)]}{d^2} \tag{1}$$

where: Z = Z value, 1.96 for 95% confidence level, p = percentage of respondents who selected a choose, 0.5, and d = confidence interval expressed in decimal, 0.5. The previous mathematical equation (1) is suitable for an indefinite sample. Since the population size in this study is known, the correct equation was as follows (2),

$$ss = \frac{ss'}{1+\frac{ss'-1}{F}} \tag{2}$$

where ss' = sample size for an infinite sample and F = population density in Putrajaya. This study's sample size was determined to be 387. Most studies require sample sizes of more than 30 but less than 500. If the expected population size is greater than 5,000, a sample size of 400 will suffice.

Thus, 500 were selected as the sample size to assure the accuracy of the sample gathered [60]. This sample size represents 0.5% of the population in Putrajaya and could reflect the entire Malaysian population. Five hundred questionnaires were distributed to Putrajaya residents using an online platform - Google Forms - and were followed by a face-to-face interview to diversify the data. A pilot test was done with 50 respondents before the distribution of the questionnaire to assess respondents' understanding and clarity of the questionnaire and to avoid any misinterpretation of the questionnaire. The final data collection took seven months, from July 2021 to January 2022.

4.2.2. Preliminary stage

A pilot study was undertaken in June 2021 to assess the reliability of the questionnaire. A total of 50 respondents were randomly picked throughout this pilot test period. Respondents were selected based on their ability to complete the questionnaire. From the comments and analysis done, the questionnaire was modified accordingly. The selection method was convenience-based, but attention

was made to ensure that the participants reflected the many elements necessary to the study.

4.2.3. Data collection

An online questionnaire and a follow-up with a face-to-face interview were used for the data verification. Since the geographical area of Putrajaya is large, the survey used two distribution methods for data collection. Both approaches in data collection are believed to be the appropriate methods used in this type of survey since they have different levels of representativeness and randomness. This study used both survey methodologies to fully utilise the benefits of these two approaches and improve the representativeness and quality of the results.

4.2.4. Scales

The Likert-type scale is the most often used research instrument for measuring views and attitudes in most social and business sciences studies. Respondents are requested to answer to convey their level of agreement with a declarative statement. On a five-point scale, each scale point might be labelled based on its agreement. The Likert scale was employed in this study to assess the level of knowledge, awareness, behaviours, and attitudes about WEEE management. The variables of WEEE management knowledge and e-waste management attitudes are 1-I have no idea, 2-I have heard about it, 3-I know, 4-I know very well, and 5- I am an expert. For the variables of e-waste management practices, the Likert scale used is 1-never, 2-rarely, 3-sometimes, 4-often, and 5-always.

4.3. Data analysis

This study employed various statistical techniques using IBM SPSS Statistics 26 software for data analysis. The mean and standard deviation (SD) were calculated to describe the data's central tendency and variability. Furthermore, reliability analysis, also known as Cronbach's alpha (α) was carried out to assess the consistency and dependability of the study's measurements. To study the link between the dependent and independent variables, multinomial logistic regression (MLR) was used. This method was acceptable since the dependent variables contained more than two levels of ordinal data. For example, the disposal EEE variable has seven distinct ordinal levels ranging from 0 to 6. These statistical approaches have been used by numerous academics and are widely acknowledged in the field of data analysis.

4.3.1. Reliability test

Table 2 shows the data central tendency. The ownership of EEE has a mean of 0.83 and the SD of EEE is 0.398, with a minimum score of 1 and a maximum score of 5 for both variables. Skewness and Kurtosis values indicate the distribution symmetry and 'peakedness' of the data, respectively [61]. In terms of knowledge and awareness, it has a mean value of 0.51, with a minimum score of 1 and a maximum score of 5 and the SD of 0.209. Next, the mean value for practices and preferences on WEEE management is 0.91 with SD of 0.327. Lastly, attitudes toward WEEE management have a mean of 0.55, respectively. The SD for attitudes toward E-waste management is 0.204.

Table 2 also presents the results of Cronbach's Alpha or reliability for each variable. For ownership of EEE the maximum Cronbach Alpha of 0.809 indicates that for independent variables, ownership of electronic and electrical appliances (EEA), $0.809 > 0.7$, the questionnaire is strong and outstanding. Knowledge and awareness about WEEE have the second highest score of Cronbach's Alpha which is 0.784 and it shows that $0.784 > 0.7$, the questionnaire is ideal for dependent variables, knowledge and awareness about WEEE. Then, followed by practices and preferences on WEEE management which has Cronbach's Alpha of 0.836 hence it shows that $0.836 > 0.7$, the questionnaire is ideal for independent variables, practices and preferences on WEEE management. Next, attitudes toward WEEE management have the second highest score of Cronbach's Alpha which is 0.893 and it shows that $0.893 > 0.7$, the questionnaire is ideal for material flow variables, attitudes toward E-waste management.

4.3.2. Multiple linear regression

The model description for the Modified R-value is represented in Table S3. With a score of 0.784, the model that adds MFA through EEE ownership explains 78.4% of the variance in projected benefits. This high score indicates that the model is significant, as evidenced by a p-value less than 0.05. Furthermore, the statistical significance of the outcome (ANOVA) is dependent on the p-value, as shown in the same table. A p-value of 0.000 means that the value of p is less than 0.05, indicating that the outcome is statistically significant.

Table S4, the combinations between the independent variables that predict the anticipated benefits. According to the significance column, all significant unit contributions have a value smaller than $p = 0.05$. Even after controlling for the variance explained by all other variables in the model, the variables of knowledge and awareness about e-waste management ($p = 0.000$), practises and

Table 2
The data central tendency and product of Cronbach's Alpha.

Variable	No of items	Mean	Std. Deviation	Cronbach's Alpha	Remarks*
Ownership of electronic and electrical appliances (EEA)	3	0.83	.398	0.809	Good & Strong
Knowledge and awareness about E-Waste	10	0.51	.209	0.784	Good & Strong
Practices and preferences on E-Waste management	9	0.91	.327	0.836	Good & Strong
Attitudes toward E-waste management	7	0.55	.204	0.893	Good & Strong

preferences on e-waste management (p = 0.004), and attitudes towards e-waste management (p = 0.005) each make a significant unique contribution to the ownership EEE. When adjusting for the variation explained by all other factors in the model, the standardised coefficient beta for knowledge and awareness of WEEE is 0.438 (p0.05), showing Attitudes toward E-waste management are the biggest unique contributor to predicted benefits in the system.

5. Results and discussion

5.1. Ownership of electronic and electrical equipment of the respondent

5.1.1. Ownership of electronic and electrical equipment

The EEE was chosen as the research subject has commonly existed in every household (Fig. 3); television (TV), washing machines (WM), refrigerator (RF), air conditioners (AC), personal desktop; desktop-pc (D-PC), and laptop-pc (L-PC), mobile phone (MP), and tablet (TAB). Each household in Putrajaya was likely to have a maximum of two TVs (42%) and one WM, RF, and AC (64.0%, 57.4%, and 33.0%, respectively). D-PC and L-PC were the most possessed product, with a maximum of three laptops (34.8%), while the most possessed D-PC were just one set (39.4%). On the other hand, tablets are relatively unknown electronic items or gadgets, with just one tablet in every 46.0% of homes.

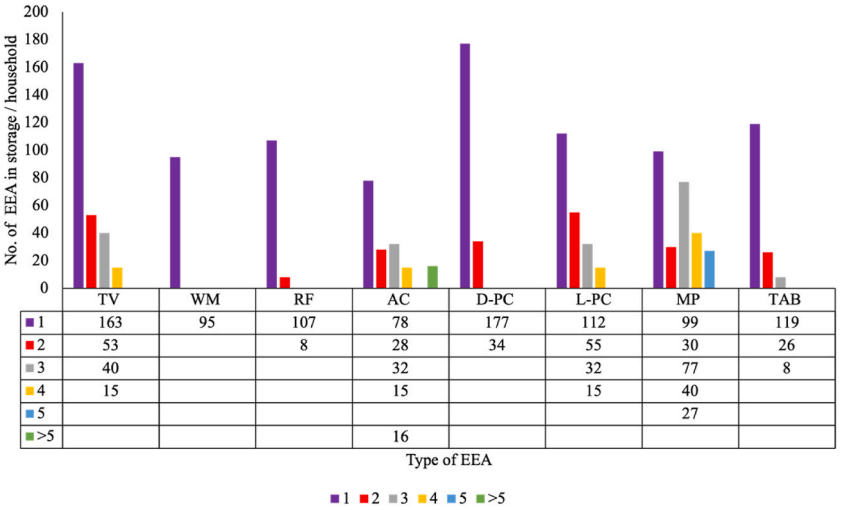
5.1.2. Electronic and electrical equipment in storage

It can be said that most of them are likely to keep their TV, AC, L-PC MP, and TAB in their house as these items can be used if repaired or kept in good hands. The statistical number shows the average respondent in Putrajaya would keep one TV, AC, and L-PC (32.4%,15.6%, and 22.4%, respectively). It was also found that some respondents have three unused MP (15.4%) and one TAB (23.8%) (Fig. 4). During an interview, several of them said that EEE such as TV, AC, MP, and L-PC have a longer lifespan than they should and that some EEE may still be utilised if fixed, even if they were outdated.

5.2. Knowledge and awareness

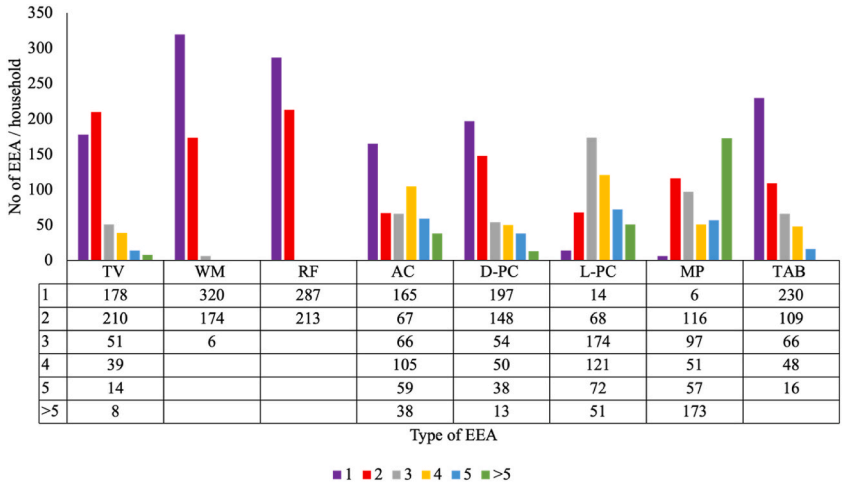
Understanding consumer knowledge and awareness of EEE is critical in understanding consumer behaviour. Table S5 in supporting information illustrates the respondent's degree of knowledge and awareness of e-waste. In general, respondents have an excellent understanding of what WEEE is (30%) and realise that WEEE is harmful (43%) and contains recyclables (32%). With that, 32% are knowledgeable that WEEE must be segregated from regular household wastes, while just 12% are unaware. Despite this, a tiny proportion of respondents (14%) had comprehensive knowledge of the effects of inappropriate WEEE disposal on humans and the environment. This finding is consistent with a previous study in Malaysia, which found that while most respondents were aware of the hazardous substances present in electronic products, only a small percentage recycled their waste [18,20,21,62,63].

When asked where the respondents were aware of the strategies and programmes for reducing and recycling WEEE by various governmental agencies and non-governmental organisations in Malaysia, the majority (30%) were aware of it, with only 16% unaware. Meanwhile, when questioned about the laws and regulations imposed by the government in dealing with WEEE management, 20.4% are unfamiliar with them, while just 5% are familiar with them. Even though the majority of respondents are unaware of the programmes, policies, and regulations involved with reducing e-waste, they believe that those activities improve Malaysian WEEE management efficiency.



	TV	WM	RF	AC	D-PC	L-PC	MP	TAB
1	163	95	107	78	177	112	99	119
2	53		8	28	34	55	30	26
3	40			32		32	77	8
4	15			15		15	40	
5							27	
>5				16				

Fig. 3. The Electronic and electrical equipment (EEE) ownership of the respondent ownership.



	TV	WM	RF	AC	D-PC	L-PC	MP	TAB
1	178	320	287	165	197	14	6	230
2	210	174	213	67	148	68	116	109
3	51	6		66	54	174	97	66
4	39			105	50	121	51	48
5	14			59	38	72	57	16
>5	8			38	13	51	173	

Fig. 4. The inventory of electronic and electrical equipment (EEE) that the respondent is currently in storage.

Interestingly, as indicated in section 4.1, the high level of knowledge and awareness among consumers in Putrajaya can be related to their high academic status. Education has a tremendous impact on moulding people's attitudes and beliefs, and it is critical in supporting sustainable behaviour. According to several studies, education provides people with the information, skills, and attitudes required for sustainable development [56,57,64]. Thus, to support sustainable consumption and production patterns, educational institutions and governments should continue to encourage education and understanding about the necessity of effective WEEE disposal and management.

5.3. *WEEE management of the respondent*

5.3.1. *WEEE disposal practices*

To determine the respondent's commitment to responsible and sustainable WEEE management, it is necessary first to learn their WEEE handling practises and preferences at home. Almost half of them (43.2%) occasionally recycle, while just 11% always recycle their e-waste. Meanwhile, the majority (47.2%) would rarely segregate their household garbage, and only 4.2% do so for e-waste. Table S6 in supporting information shows the respondent's WEEE disposal practices.

5.3.2. *Other disposal preferences and the WEEE flow*

Investigating consumer disposal preferences is critical because it shows the probable flow of WEEE, understands consumer behaviour in disposing of WEEE, and uncovers its informal stream route. Considering that most respondents would dispose of their

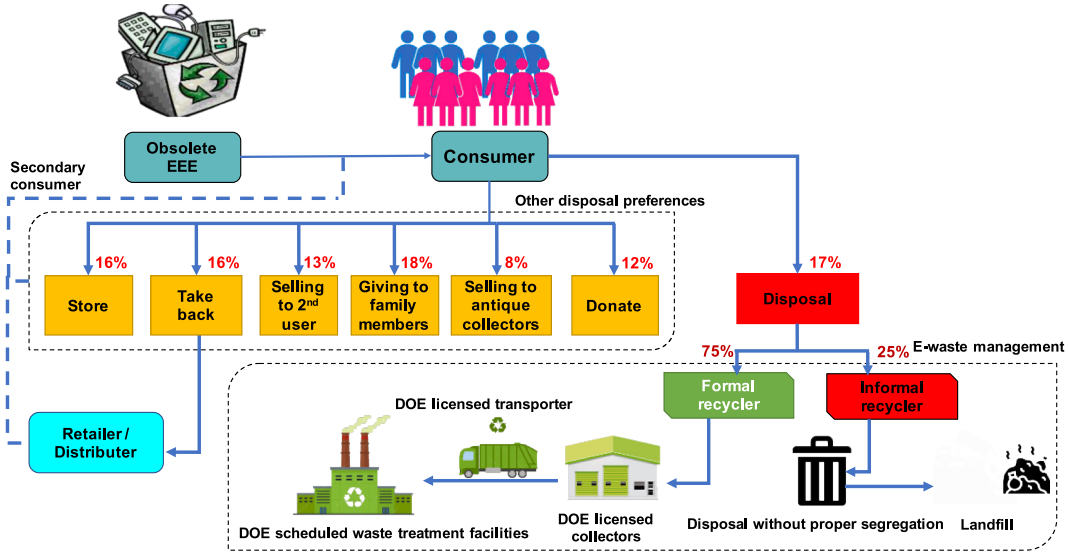


Fig. 5. WEEE flow of the respondents.

WEEE directly, two possible flows of WEEE will end up formally recycled if they segregate (75%) their WEEE from normal garbage. Alternatively, they will end up in a landfill due to poor segregation (25%). If they opt to recycle the WEEE properly, it is guaranteed that the WEEE was handled by a professional, such as the DOE. Meanwhile, if they did not, their WEEE was dumped or collected by a waste collector.

In some cases, many consumers opt to dispose of their WEEE in alternative ways, such as donating it (12%), giving it to family members (18%), selling it to antique collectors (8%), or selling it to another user (13%), the responsibility of handling the EEE becomes that of the secondary consumer. Another alternative is to return old EEE to the distributor or retailer (16%), who may provide incentives such as a discount if the buyer returns the undesired item while acquiring a new gadget. Some folks even trade their old WEEE for a new item. These alternate disposal options typically provide monetary incentives to the consumer.

Finally, consumers have a habit of storing their e-waste. A large amount of Putrajaya inhabitants continue to use outdated EEE. Televisions and air conditioners are the most kept because owners feel the equipment may be fixed and used again. Meanwhile, mobile phones and personal computers are typically carried as a keepsake or, if properly kept, may be prized as rare or antiques. Fig. 5 illustrates the WEEE flow based on the disposal practice and preferences of the consumers.

In comparison, research in Macau by Ref. [65] found that "discard into the rubbish bin" was the most popular disposal behaviour of the residents, followed by "selling to a recycling firm," "storage in the house," and "donation." About 70% of obsolete electronic goods are stored at home. This is because collecting prices in Macau are frequently low. Therefore, Macau people are unconcerned about the minor financial gain of selling old electronic items.

5.3.3. Willingness to pay (WTP)

Regarding respondent preferences, most (97.6%) think waste collectors should collect e-waste. Nonetheless, they feel they should participate in WEEE management by submitting their WEEE to recycling facilities (90.4%). Furthermore, 88% are willing to pay at least RM 10 (40%) for every pickup for WEEE disposal (Fig. 6). They agreed that the government should be responsible for WEEE disposal costs. When asked about incentives, most families opted not to receive anything in exchange, with 36.9% stating that consumers should send their WEEE to a recycling centre without expecting anything in return.

According to the previous study, the majority of respondents place high consideration on WTP [20,32,36,54,56,62,66]. This monetary incentive is intended to encourage exporters, importers, and producers to contribute to the recycling of electrical and electronic waste. Some respondents also stated that demonstrating their WTP for better WEEE management.

5.4. Perspective on sustainable WEEE management

5.4.1. Attitude toward sustainable WEEE management

Malaysia is aiming for a 40% recycling rate by 2030. Many initiatives have been implemented in governance, such as the 12th Malaysia Plan, which calls for establishing integrated waste management facilities (IWMF) [39,48,67–69]. This IWMF has several advantages, including increased energy and resource recovery and reduced environmental impact. For this to be implemented, the reaction attitude and preparation toward sustainable WEEE management must be evaluated.

When asked if the Malaysian government is dedicated to managing WEEE, 37% agree, 17% disagree, and 14% are unsure due to unfamiliarity with Malaysia's current WEEE management system because of a lack of visibility and inconsistent enforcement. However, because Putrajaya is a sustainable metropolitan model in Malaysia, most residents (65%) indicated they would be willing to adapt to the situation, while just 14% said they would not. This is because the respondents to this study are already involved in programmes aimed at reducing or recycling their regular household waste, and they think that applying such a scenario to their obsolete WEEE would not be a problem. Likewise, they strongly agree (42%) that WEEE management may be improved if we all take responsibility and work together to reduce and manage e-waste. Table S7 in supporting information shows the respondent's willingness to adapt to sustainable e-waste.

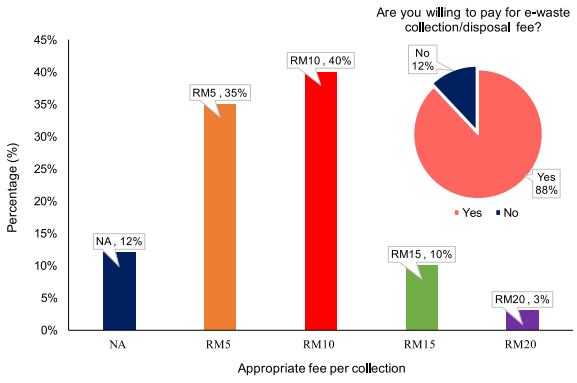


Fig. 6. Willingness to pay the respondent.

5.4.2. Responsibility toward sustainable WEEE management

Fig. 7 depicts respondents' views on who they believe should be responsible for WEEE collection. Most respondents feel that the government (36.4%) and recyclers (37.2%) are the most responsible sectors for WEEE collection. Following that, 16.8% of respondents feel that consumers are also responsible for their e-waste, and 9.6% believe shops are responsible for WEEE collection.

6. Limitations of the study and future recommendations

This research has made important strides in identifying the elements that impact consumer e-waste disposal. Several strengths add to the relevance and significance of this study. First, we successfully evaluated the disposal preferences of consumers in Putrajaya, Malaysia to provide unique insights into urban consumers' disposal behaviours, making our work a viable baseline for neighbouring counties experiencing comparable e-waste management difficulties. Furthermore, our study fills a critical gap in the current literature by examining consumer readiness for sustainable waste management, with a particular focus on e-waste management. This element of the study throws light on an area of past research that has been disregarded, offering vital insights into consumer behaviours and attitudes towards sustainable waste management practices.

Despite its strengths, our study has several limitations that should be explained. The scope of our research was confined to Putrajaya, which comprises e-waste users with a strong economic rate. This limitation may limit our findings' generalisability to a wider population. To address this, it is critical to consider performing further research in sub-urban areas, including a more varied spectrum of people and broaden the scope of the research to give a more comprehensive knowledge from the standpoint of waste management sustainability.

In future research, interviews with industry experts, observational studies, and studying individual case studies can give a more thorough knowledge of e-waste management. These methodologies provide a more in-depth examination of the intricacies and subtleties within the setting of our study. We may increase the reliability and validity of our findings by using a multi-method approach, resulting in a more robust examination of e-waste management and disposal practices. Moving forward, we offer numerous recommendations for further study based on our findings. To begin, undertaking longitudinal research would enable the investigation of changes in consumer behaviours and attitudes towards e-waste disposal over time. This longitudinal viewpoint would allow for a more thorough examination of the efficacy of legislative changes targeted at improving e-waste management practices. Furthermore, researching the impact of socio-cultural aspects on consumer behaviours and attitudes towards e-waste disposal might give useful insights for targeted interventions and awareness campaigns. Collaboration with stakeholders would improve the efficacy and application of future research and actions. Table 3 offers an overview of the limitations observed in our study as well as recommendations for further research.

In conclusion, while our study gives useful insights into consumer disposal options and readiness for sustainable waste management, it is critical to recognise its limits. We may improve our understanding of e-waste management practices and contribute to the development of more effective and sustainable waste management solutions by addressing these limitations and implementing the proposed future research objectives.

7. Conclusion

The survey found that the majority of respondents (>80%) had an adequate understanding of WEEE and are aware of the dangerous elements in the electronic and electrical equipment (EEE) they own. They also demonstrate good consumer behaviour, practises, and preferences when it comes to sustainable WEEE management practices in their homes. Even though the majority of respondents are unaware of e-waste reduction programmes, laws, and regulations, the respondents believe that government intervention has boosted WEEE management efficiency in Malaysia. Consumer behaviour in terms of WEEE disposal includes recycling at facilities, giving or selling as a used item, however, fewer people donate to a charitable contribution. This lends support to the hypothesis that raising consumer knowledge and awareness of WEEE, as well as including them in recycling programmes, leads to a higher recycling rate. To adopt more sustainable WEEE management practices, the study emphasises the necessity of knowing consumer driving factors, attitudes, and preferences. Overall, the study was successful in identifying the factors which influence consumer behaviour and WEEE management practices in Putrajaya, Malaysia.

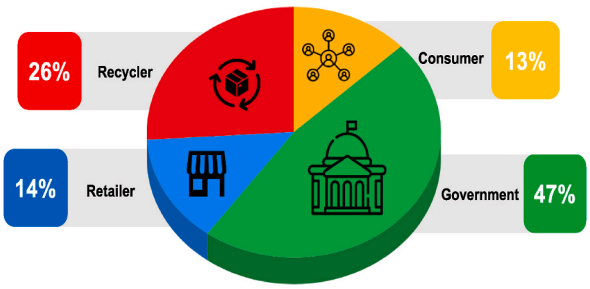


Fig. 7. Responsible sector in managing e-waste.

Table 3
Future recommendations for sustainable WEEE management.

No	Recommendation	Explanation
1	Awareness of initiatives, laws, and regulations	-Conduct separate research to establish consumer knowledge of programmes, policies, and regulations related to minimising e-waste. The table highlights the specifics of the gaps as well as recommendations for future research. -One method is to conduct a comparative study, which involves assessing the e-waste disposal practises and legislation of various nations or regions to find best practices and possible areas for development. -Simultaneously, economic analysis may be performed to determine the potential costs and advantages associated with various e-waste disposal strategies and governmental actions.
2.	Increase sample size and focus group	-While this study's sample size is 500 respondents, increasing the sample size would assist to improve the representativeness of the data and the statistical power of the analysis. This might be accomplished by surveying a bigger and more varied population, or by adopting online data-gathering tools to reach a larger audience. -By doing so, researchers could obtain a more comprehensive understanding of e-waste generation and management behaviours and attitudes across different demographics, which would help to inform policy decisions and promote effective strategies for e-waste management. -On the other hand, focus groups entail convening a small group of members to explore a given issue in depth. Focus groups could be employed in the context of e-waste disposal to investigate consumer motives and behaviours connected to the storage of obsolete electronic equipment, which is frequently a main element in e-waste development, and their disposal behaviours. -To ensure a more comprehensive understanding of the material flow of e-waste, future studies could target specific age groups, income levels, or geographic locations, thereby capturing diverse perspectives on e-waste generation and management. Research, for example, may target low-income customers to better understand their e-waste disposal behaviours and identify potential hurdles to efficient e-waste management. Policymakers and stakeholders may obtain significant insights into consumer behaviour and establish more effective e-waste management policies by doing such targeted research.
3.	More research in other Malaysia states	-It is recommended that other researchers conduct consumer behavioural studies in different states in Malaysia to identify gaps and similarities to improve the national WEEE system. This current analysis in Putrajaya can be used as a baseline study for other urban and rural areas in Malaysia

Author contribution statement

Dhiya Durani Sofian Azizi: Conceived and designed the experiments; Performed the experiments; Analysed and interpreted the data; Wrote the paper.

Marlia M. Hanafiah: Conceived and designed the experiments; Analysed and interpreted the data; Wrote the paper.

Kok Sin Woon: Analysed and interpreted the data; Wrote the paper.

Haikal Ismail: Contributed reagents, materials, analysis tools or data.

Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e17244.

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