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Fostering Sustainability: Enhancing Electronic Waste Management Awareness in Penang

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ABSTRACT

Electrical and electronic waste (E-waste) refers to devices that are damaged or no longer needed by their current owner and will be discarded. Several factors, such as increasing populations, economic development, and the shorter lifespan of electrical appliances, drive the global volume. The growing problem of electronic waste (E-waste) is a well-known global issue. This study aims to identify the factors that influence awareness of E-waste management among the Penang community in Malaysia, with a specific focus on sustainability. The primary objective is to investigate the Penang community's understanding and attitudes towards E-waste management for a sustainable future. Six independent variables were examined: awareness, knowledge, attitude, government influence, moral obligation, and subjective norm. A survey questionnaire was distributed to 384 respondents in Penang. The collected data analysed using descriptive analysis and multiple regression analysis by using Statistical Package for Social Science (SPSS) software. The findings revealed that attitude, government influence, moral obligation, and subjective norms significantly predict the Penang community's E-waste management awareness towards sustainability. Surprisingly, awareness and knowledge, as components of the Theory of Planned Behaviour (TPB), did not significantly impact sustainability-focused E-waste management awareness. In conclusion, E-waste recycling initiatives should prioritise enhancing knowledge and creating specific cues to encourage habitual recycling behaviour. This study also highlights practical and social implications for improving E-waste recycling policies.

Keywords: Attitude, Awareness, Electronic Waste (E-waste), Government Influence, Sustainability

1. INTRODUCTION

With recent technological advancements, electrical and electronic equipment has seen significant growth (Shad et al., 2020). However, these advancements have also contributed to major environmental issues, such as the increase in waste generation and challenges with its disposal. The overuse of electronic devices has led to various adverse effects, including high energy consumption, global warming, the accumulation of E-waste, and environmental pollution (Ghulam & Abushammala, 2023). According to Isernia et al. (2019), E-waste has rapidly emerged as one of the fastest-growing waste streams worldwide, exhibiting an annual growth rate ranging from 3% to 5%. By 2022, global E-waste generation had reached 62 million metric tonnes (Mt), as reported by the Global E-waste Monitor 2024, reflecting the continuous growth of this waste stream. Notably, about half of this volume—24.9 Mt in earlier years—originated from Asia (United Nations Institute for Training and Research, 2020). Projections indicate that without significant intervention, global E-waste generation could reach 74.7 million Mt by 2030 and a staggering 120 million Mt by 2050. Alarmingly, only 22.3% of E-waste was properly recycled in 2022, underscoring the urgent need for sustainable waste management solutions (Llerena-Riascos et al., 2021; Circulaire Kennis, 2024).

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In Malaysia, E-waste poses significant challenges. The country generated 364 kilotons of E-waste in 2020, amounting to approximately 11.1 kg per capita (Razali et al., 2021). The situation is even more severe in developing nations, as developed countries often export their E-waste to these regions (Ilankoon et al., 2018). For instance, in 2019, Al Jazeera reported that developed countries such as Australia, the United Kingdom, Canada, and the United States sent nearly 3,000 metric tonnes of non-recyclable plastic waste to Malaysia. This waste often includes a mix of household refuse and E-waste, such as cables from the UK, CDs from Bangladesh, and electronic scraps from Canada, the US, Japan, Saudi Arabia, and China (Abalansa et al., 2021).

Informal recycling hubs have emerged because of the demand for extracting valuable metals from E-waste. However, this has led to serious consequences, including increased airborne lead levels due to improper recycling practices. In Malaysia, illegal E-waste processing plants lacking proper filtration systems and licences have been identified as major contributors to air pollution and public health risks. These examples highlight the urgent need for better regulations and sustainable recycling practices.

E-waste generation in Malaysia continues to grow, with the global generation of end-of-life electrical and electronic equipment expected to reach 24.5 million units by 2025. Mismanaging E-waste can lead to significant environmental degradation, exploitative labour practices, and public health concerns (Camoens, 2024). Manual sorting, disassembly, and open burning methods, commonly used to separate metals from non-metals, exacerbate these problems. Malaysia's efforts align with the United Nations' Sustainable Development Goal (SDG) 12: Responsible Consumption and Production, emphasising the importance of sustainable management and optimal use of natural resources. Through programmes like KITARecycle and promoting the circular economy, Malaysia aims to enhance waste management practices to minimise the ecological footprint. Furthermore, the SDGs emphasise Goal 13: Climate Action, recognising the need to mitigate environmental pollution caused by improper E-waste disposal, and Goal 3: Good Health and Well-being, addressing the health risks posed by hazardous materials in E-waste (The Edge Malaysia, 2024). However, Malaysia still faces significant challenges, particularly in raising public awareness, strengthening regulations, and ensuring compliance with existing policies. Therefore, comprehensive studies on this issue are essential to guide policymakers, stakeholders, and the public towards effective solutions before irreversible damage occurs.

The increasing prevalence of computers, monitors, and televisions has been accompanied by a general lack of awareness regarding the potential negative consequences of electronic devices. These devices often have shorter lifespans and are produced using methods that reduce their durability. The focus on product lifespan and quality plays an essential role in exacerbating the E-waste problem. A shift in public awareness is needed, emphasising the importance of extending the life of electronic products. Computers and cell phones, for instance, often have a lifespan of fewer than two years, contributing to rapid increase of E-waste (Prabhu & Majhi, 2023). Addressing this issue is crucial to mitigating the adverse effects of E-waste on public health and the environment. A significant barrier to proper E-waste recycling is the lack of knowledge regarding hazardous E-waste and proper disposal methods. According to Azlan et al. (2021), inadequate knowledge of proper disposal methods is a key factor contributing to low awareness regarding E-waste management. In Malaysia, household recycling rates remain low, and most citizens are not familiar with the 3R practices of reducing, reusing, and recycling (Yuan et al., 2019). Only 5% of household E-waste in Malaysia is recycled and collected by Material Recovery Facilities (Yuan et al., 2019). Moreover, people often store unusable electronics at home for extended periods due to uncertainty about how to dispose of them properly.

A further challenge is the illegal export of E-waste to Malaysia. Many local businesses send E-waste to unlicensed facilities to avoid the high costs and time involved in legal disposal methods. This leads to improper waste management and environmental harm. Social pressures may also influence Malaysian communities to accept certain waste management practices, even if they have

unfavourable attitudes toward these changes. Malaysia is facing a severe issue with both legal and illegal imports of E-waste. In 2024, the Kedah Department of Environment (DOE) suspended a factory in Sungai Petani for illegally processing 350 metric tonnes of imported E-waste. The raid uncovered various environmental violations, further highlighting the need for stricter enforcement of E-waste regulations. Establishing proper facilities for legal E-waste disposal requires significant investment and adherence to strict procedures, but some local businesses prioritise cost-saving measures over environmental protection (The Star Online, 2024).

The lack of technological infrastructure, collaboration among stakeholders, and public awareness are key obstacles to effective E-waste management. This research aims to analyse the factors that influence E-waste management awareness in Penang, Malaysia, and provide actionable insights to improve sustainability in E-waste practices. This study aims to explore the Penang community's awareness of sustainable E-waste management. By understanding their knowledge and practices, the findings could provide valuable insights for future research and public initiatives. Raising awareness and fostering knowledge in this area is a key step towards driving positive change and reducing the harmful effects of E-waste on the environment and society.

2. LITERATURE REVIEW

2.1 Sustainability

Sustainability means the ability to maintain or preserve something over an extended period (Srivastava & Pathak, 2020). The importance of adopting sustainable waste management systems within communities is underscored by the need to promote environmental, economic, and social sustainability in urban areas. In modern times, sustainability is a significant focus, particularly in legislative frameworks, business models, and planning initiatives, such as the European Union's Lisbon Treaty of 2007 (Ali & Shirazi, 2022). In essence, sustainability is about taking responsibility and caring for our planet to ensure a better future. By implementing sustainable practices, organisations can diminish environmental impact, foster positive relationships with stakeholders, and contribute to a more promising future for all.

Sustainable E-waste management refers to minimising the negative social and environmental impacts of E-waste while ensuring efficient resource use and promoting long-term sustainability. This involves recycling, proper disposal, and reuse of electronic devices to mitigate the hazards they pose to human health and the environment. The primary goal of sustainable E-waste management is to reduce the production of E-waste, recover valuable materials from outdated devices through recycling, and ensure the safe handling and disposal of hazardous substances. This may involve implementing Extended Producer Responsibility (EPR) programmes, initiatives that make manufacturers responsible for their goods' complete life cycle. Additionally, it fosters a circular economy that emphasises resource efficiency while raising public awareness about responsible E-waste management. By adopting sustainable E-waste practices, we can reduce environmental harm, minimise health risks, preserve valuable resources, and support a more stable and sustainable global economy.

Achieving sustainable E-waste management also requires reducing the amount of E-waste generated by communities. By limiting the use of electronic devices or ensuring proper disposal, we can minimise E-waste production. This, in turn, helps conserve natural resources and energy, which are essential for manufacturing electronic products (Naik & Satya Eswari, 2022).

2.2 Awareness

Awareness refers to a concern for and informed interest in a particular situation or development. In the context of E-waste, awareness signifies understanding the growing volume of E-waste and its effects on both the environment and human health (Fatin et al., 2021). Awareness of the E-

waste recycling process is critical for mitigating the environmental consequences of E-waste emissions. As awareness increases, people's knowledge of effective E-waste management improves, enabling them to contribute to a healthier environment.

The Malaysian Department of Environment (2018) has a website aimed at raising E-waste awareness. It gives information on the concept of E-waste, its estimation, and how Malaysian households can properly dispose of it. When people are aware of the social and environmental impacts of E-waste, they can help reduce pollution and health risks. Focusing on the product's end-of-life cycle—through recycling, reuse, reconstruction, and proper disposal—improves the overall quality of life. E-waste contributes to visual pollution, affecting mental and physical health by degrading social well-being, economic health, and aesthetic quality. This happens when disorganised dumping of materials such as electrical components (e.g., cables, wires) occurs, affecting how people perceive the environment.

E-waste originates from a variety of sources, such as households, institutions, and industries, all of which contribute to environmental damage. An essential factor in the rising volume of E-waste is the short lifespan of modern electronic products, which encourages frequent replacements. For example, the rapid pace of phone upgrades has led to more obsolete devices being discarded (Ramzan et al., 2019). E-waste often contains valuable but also hazardous materials. Toxic substances such as arsenic, lead, cadmium, and mercury are commonly found in E-waste and can lead to serious health problems, including cardiovascular and lung diseases (Almulhim, 2022). Exposure to these harmful substances may also cause neurological and respiratory issues.

In addition to health risks, E-waste accumulation is a challenge due to limited storage space and inadequate disposal methods. Consumer awareness is critical to establishing a sustainable E-waste management system (Islam et al., 2020). Schwartz (2012) outlines three components of awareness: behaviour, practice and knowledge. These are essential in developing a long-term, economically and environmentally sustainable E-waste management system (Mahat et al., 2019). Moreover, education policies play an essential role in E-waste management. For instance, Albuquerque et al. (2020) note that Brazil's inadequate E-waste management is partly due to limited budgets and insufficient environmental education programmes. However, the level of awareness and education regarding E-waste can vary based on a country's specific circumstances. According to Fatin et al. (2021), many individuals struggle to translate their awareness into action, maintaining unsatisfactory attitudes toward environmental issues.

2.3 Knowledge

Knowledge refers to the facts, theories, skills, and information gained through experience and education (Hamzah et al., 2020). People who are more knowledgeable about recycling are more likely to participate in recycling activities. Knowledge-based and learning systems face significant challenges in all aspects of knowledge management due to the complexity of knowledge representation. Knowledge is a critical factor in ensuring the success of sustainable E-waste management practices. If citizens are not educated about environmental knowledge, they are less likely to make the effort to properly dispose of their electronic devices (Ng, 2020).

Environmental knowledge, a subset of knowledge, refers to the ability to understand and recognise the interrelationships within environmental systems and assess their health (Sumargo, 2018). Environmental education is seen as a continuous and lifelong process that is an integral part of a citizen's holistic education. It aims to build knowledge, attitudes, skills, and habits that contribute to sustainability. For the Malaysian community, especially in Penang, understanding environmental knowledge is crucial due to the significant consequences of improper disposal of electronic devices. Although there is no universal definition of environmental knowledge, scholars have identified key principles such as ecological understanding, cognitive ability to analyse environmental issues, and behavioural patterns aimed at reducing an individual's environmental impact (Liobikien & Pokus, 2019).

The environmental knowledge acquired by the Penang community influences their actions regarding E-waste disposal, leading to an informed understanding of the environmental and public health impacts of E-waste. A higher level of awareness about environmental problems may encourage the public to engage in recycling practices for E-waste (Awasthi & Li, 2018). Research has shown a clear relationship between knowledge and E-waste management awareness in promoting sustainability within the Penang community. Therefore, it is essential to incorporate environmental education from an early age to enhance knowledge and awareness, which in turn will foster the behaviours needed for sustainable E-waste management practices. Past studies have consistently demonstrated that knowledge is a key factor in promoting sustainable E-waste management in the Penang community (Sulaiman & Chan, 2019).

2.4 Attitudes

Attitude can be defined as a positive or negative mental state of preparedness, shaped by experience, that influences a person's reactions to people, objects, and situations. The three primary components of attitude are affect, behaviour, and cognition (Liu et al., 2018). Affect is influenced by peer groups, instructors, parents, and leaders. Cognition refers to beliefs, opinions, and perceptions, with beliefs being the most crucial component, reflecting favourable or unfavourable views about an object or person. Behaviour refers to a person's intention to act in a certain way toward someone or something. Thus, attitude encompasses how individuals feel (affective), what they believe (cognitive), and how they behave (behavioural) (Aboelmaged, 2021).

Attitude shapes how individuals respond to the objects and events they encounter and plays a vital role in decision-making, particularly in environmental protection. It is a key factor in influencing people's decisions to avoid polluting the environment (Iyer, 2018). Environmental attitudes are closely tied to an individual's self-concept and their perception of their role within the natural environment.

For instance, in Ghana, waste management challenges are exacerbated by the public's negative attitude toward environmental protection. Academic institutions, due to the rise of information and communication technology, have become significant users of electronic equipment, with students being a major source of E-waste. Given the rapid pace of technological advancement, students' attitudes toward E-waste generation, collection, and segregation are critical for shaping future behaviour. These attitudes, particularly their emotional components, are influenced by peer groups, parents, instructors, and leaders.

Research has shown a clear relationship between attitude and E-waste management awareness in promoting sustainability among Malaysian communities. Data collected from respondents, primarily students, revealed that most had sufficient knowledge about E-waste management due to routine exposure to environmental activities. This demonstrates that a shift in attitude leads to a shift in behaviour, marking a critical turning point in addressing the E-waste problem (Sulaiman & Chan, 2019).

2.5 Government Influence

Government is defined as a political system that controls an organised community, typically comprising three branches: legislative, executive, and judiciary. Government policy means the statement of the government's political programmes, objectives, and intentions regarding specific causes. The importance of government policy cannot be overstated, as it exists to ensure that citizens abide by the law. Policies provide a rationale for why certain actions should be taken and guide the direction of those actions. Public issues can emerge in numerous ways, each requiring a unique policy response (Liu et al., 2023).

Governments establish various policies that serve as guidelines for businesses. These policies can influence fiscal matters such as trade, taxation, regulations, subsidies, interest rates, and licensing. Businesses must remain flexible and adaptive to changing policies and regulations. Government policies function at various levels, from national to local, including state and municipal governments, each with its own set of rules. Additionally, international treaties can influence how businesses conduct their operations, highlighting the vital role government policies play in maintaining the smooth functioning of society (Yong et al., 2021).

In the context of E-waste recycling, data indicates that 16% of respondents report low awareness and ineffective government policies, while 13% cite a weak formal collection system and ineffective policies. These factors discourage citizens from following proper E-waste disposal procedures (Ramzan et al., 2019). In response, the Chinese government has implemented various initiatives to promote formal recycling, such as the 'old for new' event to reduce informal recycling centres. Additionally, a special fund was established, and subsidies were provided to encourage formal recyclers to adopt sustainable E-waste management practices. Research has demonstrated a clear relationship between government policy and awareness of E-waste management in promoting sustainability. While laws have been enacted to restrict the import of E-waste and curb informal recycling activities, these measures alone have not been sufficient, as consumer participation in formal recycling remains low (Iyer, 2018).

2.6 Moral Obligation

Perceived moral obligation refers to individuals' understanding of their moral duty to behave ethically when confronted with ethical dilemmas (Rezaei & Ho, 2021). This concept encapsulates an individual's intrinsic motivation to engage in specific behaviours aligned with their personal sense of duty or ethical responsibilities. Moral considerations play a crucial role in motivating individuals to take action, particularly when their own self-interest conflicts with the interests of others. When one's self-interest conflicts with the interests of others, an individual's moral concerns play a significant part in motivating them (Kumar, 2019). E-waste management promotes the proper disposal, recycling, and reuse of electronic devices, reducing the negative environmental impacts associated with E-waste. Individuals who value environmental responsibility may feel a moral obligation to engage in sustainable E-waste management to minimise harm to the environment and preserve natural resources.

2.7 Subjective Norm

Subjective norm refers to a person's adoption of a specific conduct under societal pressure. Social pressure refers to the influence exerted on individuals by their interpersonal networks and immediate surrounding communities, which is shaped by a mix of injunctive and descriptive norms. These standards are based on the impression of what is considered acceptable or undesirable conduct within a certain social context (Singh et al., 2018). The subjective norm is an additional significant criterion within the Theory of Planned Behaviour (TPB). This concept, proposed by Fishbein and Ajzen in 1975, includes both external and internal influences. External influences refer to other people or organisations, while internal influences refer to a person's relationships. In addition, perceived behavioural control, often referred to simply as behavioural control, relates to an individual's perception of how easy or difficult it is to carry out a certain action (Ajzen,1991). It takes into account a person's perception of his or her ability to compete. Subjective norms reflect the perceived expectations of important individuals or groups regarding E-waste management practices. Promoting sustainable E-waste management within Malaysian communities can shape positive subjective norms and encourage responsible behaviours (Kumar, 2019).

2.8 Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour (TPB) is a psychological framework introduced by Ajzen (1991) to predict and understand human behaviour. TPB posits that behaviour is influenced by three

primary components: attitude, subjective norm, and perceived behavioural control. These components shape an individual's behavioural intentions, ultimately guiding actual behaviour. TPB has been widely applied in studies related to environmental sustainability, including waste management and recycling practices (Kumar, 2019; Lau et al., 2021).

This study extends the TPB framework to include additional factors, such as awareness, knowledge, government influence, and moral obligation, alongside the traditional components of attitude, subjective norms, and perceived behavioural control. This integrated model comprehensively explains the factors influencing E-waste management behaviours within the Penang community. By analysing these factors, the study explains how intentions are formed and transformed into sustainable actions, offering practical insights for policymakers and stakeholders.

3. RESEARCH METHODOLOGY

3.1 Conceptual Framework

Figure 1 illustrates the study's conceptual framework. The framework highlights six factors, awareness, knowledge, attitude, government influence, moral obligation, and subjective norms, as extensions of the TPB in the context of sustainability E-waste management. These factors are expected to play a crucial role in reducing E-waste.

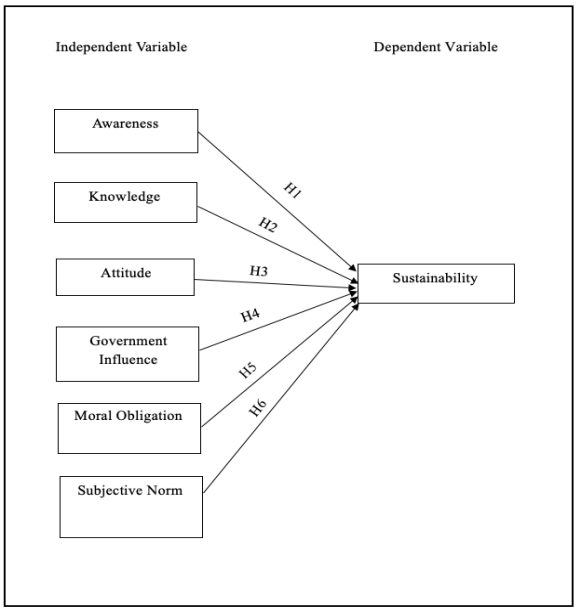

Figure 1. Conceptual Framework

3.2 Research Design

The study used a quantitative research method with a questionnaire as the instrument. Quantitative data was collected using survey forms with questions related to the study (Scribbr, 2023a). The questionnaire included questions linked to independent variables (awareness, knowledge, attitudes, government influence, moral obligation, subjective norm) and dependent variables (sustainability). The study framework was established. Data was collected through questionnaires to answer the research questions and analysed using statistical analysis with the SPSS tool.

3.3 Population and sample

The total population of the Penang community is 1,740,405 people from Penang Island and Penang Mainland, which is more than 1 million people. Penang communities in these five districts are separated into five specific areas: Southwest Penang, Northeast Penang, Central Seberang Perai, North Seberang Perai, and South Seberang Perai (See Table 1). Therefore, this study referred to the Krejcie & Morgan's (1970) table to determine a minimum number of 384 respondents.

In this study, the targeted population was the Penang community, aged 21 to 60 and above, as this age group had the purchasing power for electronic products. In contrast, individuals under 20 were excluded due to their lower purchasing capacity, as they were not legally adults and had yet to enter the workforce formally.

Table 1 Number of People by Districts in Penang Island and Penang Mainland, Malaysia

District	Population	Sample
Southwest Penang	237,738	52
Northeast Penang	184,007	41
Central Seberang Perai	422,990	93
North Seberang Perai	339,095	75
South Seberang Perai	556,575	123
Total	**1,740,405**	**384**

Source: City Population, 2020

3.4 Study Instrument

A questionnaire was used as the instrument of data collection. The questionnaire contained three sections: A, B, and C. In section A, the demographic details include name, gender, age, race, number of years residing in Penang, district, educational background, occupation, and whether the respondent had ever heard about E-waste. Sections B and C included items related to awareness, knowledge, attitude, government influence, moral obligation, subjective norms, and sustainability, which respondents were required to complete. All questions were compulsory for respondents to answer. The study targeted individuals who worked, studied, or resided in Penang State, as the research aimed to assess E-waste management awareness towards sustainability among the Penang community. Each variable was measured using a five-point Likert-type scale ranging from 1 to 5, where 1 represented 'Strongly Disagree', 2 indicated 'Disagree', 3 represented 'Neutral', 4 signified 'Agree', and 5 stood for 'Strongly Agree' (Tanujaya et al., 2023).

3.5 Variables and Items

Table 2 presents the variables and corresponding items used in this study.

Table 2 Variables and Items

Variables	Variables Measured	Adapted Items	Sources of Data	No. of Items
IV	Awareness	1. I am aware that E-waste is harmful to animals.	(Almulhim, 2022)	
		2. I am aware of harmful effect of E-waste to our health.	(Awasthi & Li, 2018)	
		3. I am aware of harmful effect of E-waste to environment.	(Kumar, 2019)	5
		4. I am aware of law and policies that are enhanced by the government about E-waste.		

Variables	Variables Measured	Adapted Items	Sources of Data	No. of Items
		5. I am aware of the process of recycling E-waste properly.		
IV	Knowledge	1. I know that E-waste may pollute the environment. 2. I know the negative effect of selling used electronic products to informal recyclers (waste collectors). 3. I know what types of E-waste can be recycled. 4. I understand the 3R for E-waste management. (3R-Recycle, Reuse, Reduce) 5. I learned the knowledge about E-waste management.	(Jahan & Mim, 2023) (Mohammed, 2022) (Zhao, et al., 2023)	5
IV	Attitude	1. Recycling E-waste makes me feel very satisfied. 2. Recycling E-waste contributes to society. 3. Recycling E-waste is everyone's responsibility. 4. I will share my awareness of E-waste management with everyone. 5. Proper E-waste management would contribute to a healthy and safe environment.	(Kumar, 2019) (Wang et al., 2018) (Zhao et al., 2023)	5
IV	Government Influence	1. I understand the relevant laws and regulations for the recovery of E-waste. 2. I understand exactly what I have to do to obey the law and recycle E-waste. 3. Local authorities provide recycling bins for residents to recycle E-waste. 4. There is a need for the government to strengthen laws pertaining to E-waste management. 5.The government should establish educational platforms to promote understanding and proficiency in E-waste management.	(Andeobu et al., 2021) (Anwar, 2020) (Awasthi & Li, 2018) (Zhao, et al., 2023)	5
IV	Moral Obligation	1. I have to take responsibility for recycling E-waste. 2. It would be unethical of me not to recycle waste. 3. I never dispose of E-waste by throw into rivers or sea. 4. I never dispose E-waste as any way I want to. 5. I would feel guilty if I did not perform recycling.	(Aboelmaged, 2021) (Kumar, 2019)	5
IV	Subjective Norm	1. Many people want me to separate E-waste and general waste while recycle the waste. 2. My friends always teach me knowledge about E-waste management. 3. My family expect me to safely dispose the old electronic equipment.	(Laeequddin et al., 2022) (Wang et al., 2018)	5

Variables	Variables Measured	Adapted Items	Sources of Data	No. of Items
		4. I heard from various sources that it's important to recycle E-waste with licensed recyclers. 5. The media influence me to recycle E-waste.		
DV	Sustainability	1. I always recycle electronic equipment that already broke. 2. I will continuously be enhancing my knowledge in managing E-waste responsibly. 3. I will separate E-waste out of the other general waste when throw. 4. I will try to repair the broken electronic equipment rather than just buying a new one. 5. I will pay for licensed recycler to dispose my E-waste.	(Jahan & Mim, 2023) (Lau et al., 2021)	5

4. DISCUSSION OF THE FINDINGS

4.1 Demographic characteristics of Respondents

Table 3 shows the background of respondents living in Penang. The proportion of male and female respondents was almost equal, with 187 males (48.7%) and 197 females (51.3%). Whereas, regarding age, the largest group of respondents were between 21 and 30, representing 63% of the sampled respondents. The respondents' racial distribution showed that the majority were Chinese, with a total of 280 (72.9%). The respondents' duration of stay in Penang revealed that 174 individuals (45.3% of the sample) had lived in the state for 0–5 years. This was followed by respondents who had stayed for 6 – 10 years, totalling 57 individuals (14.8%). Furthermore, 47 respondents (12.2%) had lived in Penang for 11–15 years. Lastly, 106 respondents (27.6%) had lived in Penang for more than 15 years. Finally, respondents who had resided in Penang for over 15 years were 106, representing 27.6% of the sample population. On the other hand, educational background, as noted by Al-Khateeb et al. (2017), plays a crucial role, as individuals with higher education are generally more likely to respond positively to external stimuli. The majority of the respondents possessed a higher level of educations, including Diploma, Bachelor's Degree, Master's, and PhD qualifications. These 222 respondents constituted 57.8% of the sample. Most respondents were also employed, with 206 individuals comprising 53.6% of the sampled population. The level of awareness of E-waste in the study area shows that a significant proportion of the population, 299 respondents (77.9%), are aware of E-waste issues. In contrast, approximately 85 respondents (22.1%) claimed that they were not aware of E-waste issues.

Table 3 Distribution of the Respondents by Demographic (n=384)

Demographic Background		Frequency (n)	Percentage (%)
Gender	Male	187	48.7
	Female	197	51.3
Age	21-30	242	63.0
	31-40	40	10.4
	41-50	45	11.7
	51-60	26	6.8
	61 and above	31	8.1
Races	Chinese	280	72.9

Demographic Background		Frequency (n)	Percentage (%)
	Malay	73	19.0
	India	31	8.1
How many years have you been staying in Penang State?	0-5 years	174	45.3
	6-10 years	57	14.8
	11-15 years	47	12.2
	> 15 years	106	27.6
District	North Seberang Perai (Butterworth, Kepala Batas)	72	18.8
	Central Seberang Perai (Bukit Mertajam)	89	23.2
	South Seberang Perai (Nibong Tebal)	78	20.3
	Northeast Penang Island (Georgetown)	74	19.3
	Southwest Penang Island (Bayan Lepas)	71	18.5
Education Background	Primary Education (Standard 1 to 6)	37	9.6
	Secondary Education (SPM)	72	18.8
	Post-Secondary Education (STPM/Matriculation)	53	13.8
	Higher Education (Diploma/Bahelor's Degree/Master's Degree/PhD)	222	57.8
Occupation	Student	117	30.5
	Employed	206	53.6
	Unemployed	61	15.9
Have you ever heard about what is E-waste?	Yes	299	77.9
	No	85	22.1

4.2 Descriptive Analysis

The results from the questionnaire are presented separately in the subsequent sub-section. Every variable was assessed using a 5-point Likert scale. Table 4 outlines the classification of mean scores, starting from low level to high level.

Table 4 Classification of Mean Score Level

Mean level	Indication
High	3.34 to 5.00
Medium	1.67 to 3.33
Low	1.00 to 1.66

Table 5 Descriptive Analysis

Variables	Number of Respondents (N)	Mean	Std. Deviation
Awareness	384	3.79	1.06
Knowledge	384	3.65	1.02
Attitude	384	3.88	1.05
Government Influence	384	3.55	1.08
Moral Obligation	384	3.83	1.12
Subjective Norm	384	3.43	1.14
Sustainability	384	3.58	1.12

Table 5 presents the results, indicating that the mean score for the dependent variable, sustainability, was 3.58. The mean scores for the independent variables were as follows: awareness (3.79), knowledge (3.65), government influence (3.55), and moral obligation (3.83). Overall, the mean scores for all variables were relatively moderate but fell within the high category ("Agree") as classified in Table 4. Among these, attitude exhibited the highest mean score at 3.88, while subjective norm had the lowest mean score at 3.43.

The standard deviation for awareness was 1.06, while attitude recorded a standard deviation of 1.05. The standard deviations for moral obligation and sustainability were both recorded at 1.12. Government influence had a standard deviation of 1.08. Additionally, the standard deviation for knowledge was the lowest at 1.02, while the subjective norm exhibited the highest standard deviation at 1.14. Consequently, these results indicate that the respondents' scores were not closely clustered around the mean.

4.3 Reliability Analysis

Reliability analysis addresses the consistency of the study's outcomes. The reliability test assesses the internal consistency of the data. Cronbach's Alpha is commonly used to determine internal reliability in surveys that include dichotomous or scale-based questions. It can also be defined as a measure of how closely related a group of items are.
Cronbach's Alpha values are considered to indicate poor reliability if below 0.60, average reliability if between 0.60 and 0.70, good reliability if between 0.70 and 0.80, and very high reliability if above 0.80.

Table 6 Results of Reliability Test

Variables	Number of Items	Cronbach's Alpha	Internal Consistency
Awareness	5	0.874	Good
Knowledge	5	0.836	Good
Attitude	5	0.891	Good
Government Influence	5	0.864	Good
Moral Obligation	5	0.907	Excellent
Subjective Norm	5	0.892	Good
Sustainability	5	0.889	Good

Table 6 shows Cronbach's Alpha values for all variables. An alpha value greater than 0.80 is considered satisfactory or reliable (Taber, 2018). Moral obligation has the highest value among the independent variables, with Cronbach's Alpha value of 0.907. This is followed by subjective norm with Cronbach's Alpha value of 0.892, and attitude with 0.891, ranking second and third highest, respectively. Additionally, awareness and government influence recorded Cronbach's Alpha values of 0.874 and 0.864, respectively, both indicating good internal consistency. Furthermore, knowledge had the lowest Cronbach's Alpha value among the independent variables, at 0.836; but it still demonstrated good internal consistency in the reliability test. Lastly, the dependent variable of the research, sustainability, recorded a Cronbach's Alpha value of 0.889, indicating excellent internal consistency based on the research data.

4.4 Correlation Analysis

Correlation analysis is a statistical technique used to determine the strength and presence of the relationship between two different factors. It is commonly employed to assess the degree of association between variables. The correlation coefficient, R, ranges between -1 and 1 (Senthilnathan, 2019). A value of -1.00 indicates a perfect negative correlation, while a value of +1.00 signifies a perfect positive relationship. A value of 0.00 implies that no correlation exists (Nickolas, 2021). The relevance of a correlation coefficient of a specific value affects the size of the population from which it was calculated. Table 7 presents the relationship between the

independent and dependent variables. The correlation values of all variables fall within the range of 0.61 to 0.80, indicating a high positive correlation between the independent variables and dependent variables in this study.

Table 7 Inter-Correlation Between Variables

Correlations								
		Awareness	Knowledge	Attitude	Government Influence	Moral Obligation	Subjective Norm	Sustainability
Awareness	Pearson Correlation	1	.778**	.755**	.685**	.714**	.600**	.682**
	Sig. (1-tailed)		<.001	<.001	<.001	<.001	<.001	<.001
Knowledge	Pearson Correlation	.778**	1	.761**	.743**	.710**	.705**	.708**
	Sig. (1-tailed)	<.001		<.001	<.001	<.001	<.001	<.001
Attitude	Pearson Correlation	.755**	.761**	1	. 703**	.819**	.677**	.753**
	Sig. (1-tailed)	<.001	<.001		<.001	<.001	<.001	<.001
Government Influence	Pearson Correlation	.685**	.743**	.703**	1	. 737**	. 705**	. 778**
	Sig. (1-tailed)	<.001	<.001	<.001		<.001	<.001	<.001
Moral Obligation	Pearson Correlation	.714**	.710**	.819**	. 737**	1	. 646**	. 794**
	Sig. (1-tailed)	<.001	<.001	<.001	<.001		<.001	<.001
Subjective Norm	Pearson Correlation	.600**	.705**	.677**	. 705**	. 646**	1	. 755**
	Sig. (1-tailed)	<.001	<.001	<.001	<.001	<.001		<.001
Sustainability	Pearson Correlation	.682**	.708**	.753**	. 778**	. 794**	. 755**	1
	Sig. (1-tailed)	<.001	<.001	<.001	<.001	<.001	<.001	

Moral obligation towards sustainability recorded the highest correlation value at 0.794 (79.4%). Next, the second-highest correlation was observed between government influence and sustainability, with a value of 0.778 (77.8%). This was followed by subjective norm, which had the third-highest correlation value at 0.755 (75.5%). Attitude towards sustainability ranked the fourth-highest correlation at 0.753 (75.3%), while knowledge ranked fifth at 0.708 (70.8%). Lastly, awareness towards sustainability recorded the lowest correlation value among the variables at 0.682 (68.2%). The table shows that all independent factors such as awareness, knowledge, attitude, government influence, moral obligation, and subjective norm have a positive relationship with the dependent variable, sustainability. The correlation between awareness and sustainability is significant (0.682 with a significance level less than 0.001), indicating a strong relationship. This suggests that greater awareness of sustainability issues may lead to greater focus on sustainable practices. Similarly, the correlation between knowledge and sustainability is also significant (0.708 with a significance level less than 0.001), demonstrating a strong relationship. The Penang community, with its strong knowledge of E-waste management and sustainability, may be more likely to adopt sustainable practices. A positive attitude towards sustainability can motivate people to engage in actions such as recycling E-waste. The correlation between government influence and sustainability is significant (0.864 with a significance level less than 0.001), indicating a strong positive

relationship. The perception of strong government influence through regulations and policies can motivate responsible E-waste management in Penang. In addition, the correlation between moral obligation and sustainability is also significant (0.907 with a significance level less than 0.001), reflecting a strong positive relationship. A strong sense of moral obligation can encourage the Penang community to engage in sustainable practices related to E-waste management. Lastly, the correlation between subjective norms and sustainability is significant (0.892 with a significance level less than 0.001), indicating a positive strong relationship.

4.5 Regression Analysis

Multiple regression was used to assess the influence of one or more independent variables on the dependent variable. This method allows researchers to assess how accurately independent variables measure the value of the dependent variable (Scribbr, 2023b). The variables were then evaluated using a linear regression model, and the results are presented in the following tables: model summary, ANOVA, and coefficients.

Table 8 Model Summary

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.873[a]	0.761	0.758	0.55216

R^2 is commonly referred to as the correlation coefficient. According to the model summary for sustainability, the value of R^2 is 0.761 (76.1%). The value of 0.761 implies that 76.1% of the variance in the dependent variable, sustainability, is explained by the independent variables in this research. Moreover, the modified R^2 provides a more accurate estimate of the model's generalisability. On the other hand, the model summary for sustainability shows an Adjusted R^2 value of 0.758 (75.8%), which is close to the R^2 value (See Table 8).

Table 9 ANOVA

	Model	Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	366.717	6	61.119	200.469	<.001 [b]
	Residual	114.940	377	.305		
	Total	481.657	383			

Based on the ANOVA results in the sustainability model (Table 9), the outcome describes the overall variance of the regression model of this research. The F-ratio was used to measure the overall fit of the model, with an F-value of 200.469. This was calculated by dividing the Mean Square Regression (61.119) by the Mean Square Residual (0.305). According to the correlation of variables table, the significance value ('Sig.') is reported as < .001[b], indicating that the independent variables effectively explain the variance in the dependent variable. Therefore, the overall decline in the outcome is significant.

Table 10 Coefficient Analysis

Coefficients[a] Model	Beta	T	Sig.
(Constant)		-554	.580
Awareness	0.054	1.214	.226
Knowledge	-0.028	-.574	.566
Attitude	0.092	1.802	.072
Government Influence	0.249	5.635	<.001
Moral Obligation	0.328	6.789	<.001
Subjective Norm	0.292	7.426	<.001

Based on the coefficient table for sustainability (Table 10), the influence of attitude (β = 0.092, t = 1.802, p = 0.072), government influence (β = 0.249, t = 5.635, p = <0.001), moral obligation (β = 0.328, t = 6.789, p = <0.001), and subjective norm (β = 0.292, t = 7.426, p = <0.001) on the dependent variable was examined by the standardised beta coefficient. The results indicate that government influence, moral obligation, and subjective norm have a significant impact on sustainability, while awareness and knowledge were not found to be statistically significant (See Table 10).

Table 11 Summary of Hypothesis Testing Results

	Hypothesis	**Remark**
H_1	There is a relationship between awareness and the sustainability of E-waste management.	Rejected
H_2	There is a relationship between knowledge and the sustainability of E-waste management.	Rejected
H_3	There is a relationship between attitude and the sustainability of E-waste management.	Accepted
H_4	There is a relationship between government influence and the sustainability of E-waste management.	Accepted
H_5	There is a relationship between moral obligation and the sustainability of E-waste management.	Accepted
H_6	There is a relationship between subjective norm and the sustainability of E-waste management.	Accepted

5. CONCLUSION

In summary, this study, which was conducted among the Penang community, has highlighted that awareness of E-waste management in relation to sustainability is a crucial factor in evaluating the community's knowledge, attitudes, perceptions of government influence, moral obligations, and subjective norms. The results revealed that attitude, government influence, moral obligation, and subjective norms significantly impact sustainability, while awareness and knowledge do not show a significant relationship with sustainability. Thus, the findings indicate that attitude, government influence, moral obligation, and subjective norms have a significant impact on sustainability, and the aim of the study has been achieved.

To reduce the amount of E-waste transported to landfills, it is essential to promote and encourage E-waste recycling activities among the public. Although awareness and knowledge may not directly influence sustainability, this study underscores the importance of shaping attitudes, government policies, and moral obligations to enhance public awareness with E-waste management and its impact on environmental well-being. Providing the public with comprehensive information on E-waste recycling, including its benefits, proper management practices, segregation methods, and registered collection centres, is essential. Government bodies, with support from NGOs, must ensure that the public has access to accurate and sufficient information. In turn, the public should take responsibility for managing their E-waste by recycling it responsibly.

The study concludes that improper handling of E-waste poses risks to both human health and the environment, underscoring the need for proper disposal methods, such as using designated E-waste collection centres and recycling bins rather than storing them at home. Future research could explore E-waste generation and disposal patterns, as well as the development of advanced recycling and collection technologies. Furthermore, addressing challenges such as regulatory enforcement, strengthening the informal sector, creating transparent recycling systems, conducting public awareness campaigns, and providing incentives for E-waste recycling will be essential to achieving a sustainable future.

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