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Integrating government policy and facility-based interventions in improving E-waste recycling: Incentives as a moderator of sustainability impact

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Abstract

Electronic waste (e-waste) is the fastest-growing waste stream globally, producing over 53.6 million metric tons in 2022 and projected to increase to 74 million tons by 2030. Unfortunately, only 17% of worldwide e-waste is collected and recycled properly, resulting in millions of tons of improperly discarded items that can significantly harm the environment. This issue is also prevalent in Malaysia, which generates an estimated 280,000–365,000 tons of e-waste annually, with low recycling rates among households. This study investigates the factors contributing to low household e-waste recycling in Malaysia. Three factors were assessed through a quantitative survey of 384 urban households in Ipoh, a northern Malaysian state. Facilities and government policy were identified as independent variables, while incentives served as a moderating variable to enhance household recycling. The findings suggest that incentives influence government policy, whereas facilities are unaffected by incentives in promoting recycling. As e-waste volumes grow, Malaysian households have largely resisted integrating e-waste recycling into their daily routines, often discarding gadgets improperly or selectively. The researchers emphasize the urgent need for comprehensive strategies, including increased consumer awareness, accessible take-back programs, incentive schemes, and stricter policies to improve e-waste recycling and sustainability. The study offers integrated recommendations for policymakers and stakeholders to enhance recycling practices and highlights areas for future research in sustainable waste management.

Keywords: Circular economy, E-waste recycling, Infrastructure development, Malaysia, Sustainability.

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1. Background

Today, electronics are commonly found in most households and appear in various forms and functions. E-waste is generated when these electronics reach the discard stage of their product lifespan, become unusable, and are obsolete [1]. The primary concern was that approximately 80% of the global e-waste was not disposed of systematically, which directly revealed a devastating effect on the environment [2]. In contrast, the amount of discarded e-waste rises sharply, as the estimate for e-waste volume in 2021 reached 52.2 million metric tons, compared to 44.7 million metric tons in 2016 [3]. Currently, with 150 landfills nationwide, landfilling is the primary waste disposal method in Malaysia [4] .

Lacking proper e-waste recycling efforts to discard e-waste increases the difficulty for components to self-disassemble and decompose, consuming a lot of space, and this disrupts the development of areas. Also, landfills pose a threat to the ecosystem as toxins contained within electronic gadgets and hazardous substances can result in serious threats to the environment, human beings, animals, and marine creatures [5]. These harmful substances at landfills are exposed to the environment in the form of gas (methane and carbon dioxide) emissions, resulting in global warming and acidification, or being absorbed into the soil, and potentially moving towards the rivers, which will pollute the water supply [5].

In Malaysia, the Department of Environment has conducted studies in various designated areas, showing that the volume of household e-waste is rapidly rising and is estimated to reach approximately 53 million in 2020 [6]. In fact, there is a lack of e-waste management systems to regulate proper disposal throughout the country [7]. Critically, the key category of people contributing to vast quantities of e-waste is Malaysian households, the end consumers. If a higher population generates more waste, an enormous amount will be produced in an area with such a population if recycling is not thoroughly implemented. Perak ranks in the top fifth in population among the states in Malaysia. Ipoh, the capital city of Perak with a population of 737,861, is also known as the third-largest city in Malaysia [8]. Emphasizing the e-waste scenario occurring in Perak state, where 593.87 tons of e-waste were disposed of in 2017, as reported in the Malaysia Environmental Quality Report 2021 [9], the research focus for this paper will be to identify factors behind the lack of e-waste recycling among households in Ipoh.

The e-waste scenario in Perak might be linked to certain factors, such as the availability of recovery facilities. According to statistics provided by the electronic scheduled waste information system in 2018, only two full recovery facilities are available in Perak [9]. It implies insufficiency and a lack of facilities to manage the stockpile of e-waste. Additionally, news has been published regarding the government's amendment of the Environment Act to enforce stricter rules for the collection of e-waste. Reportedly, amendments are intended to fill gaps in the current regulatory framework, and nationwide consumers are to be included in the responsibility for future systematic e-waste disposal [10].

2. Literature Review

According to the Global E-waste Monitor 2020, e-waste is the fastest-growing waste stream in the world, generating more than 53.6 million metric tons in 2019, and it is expected to grow to 74 million tons by 2030 [11]. Shockingly, only 17% of global e-waste is appropriately collected and recycled, leading to substantial environmental hazards. Several countries are experiencing this problem; one example is Malaysia, which produces an estimated 280,000–365,000 tons per year but has a very low recycling rate, especially from households [9].

Electronic waste is generated mainly by households and businesses, which dispose of devices like televisions even before they reach the end of their functional lifespan [12]. Universities contribute significantly to e-waste through information and communication technology (ICT) equipment [2]. E-waste contains toxic substances such as mercury, lead, cadmium, and chromium, which pose serious health risks, including neurological disorders, kidney impairment, and brain-related illnesses [12].

Therefore, this study aims to investigate the determinants of the low rate of household e-waste recycling in Malaysia. Using a quantitative survey method, data were collected from 384 urban households in Ipoh, specifically regarding the availability of recycling facilities, public awareness, incentives, and government policies, among other factors.

Literature suggests that increased consumption, rapid product obsolescence, and low repair option volumes may have contributed to increasing volumes of e-waste. From 2010 to 2019, the global amount of e-waste surged by around 60%, which is ten times more than the general municipal waste (53.6 million tons) produced during the same period. It is forecasted to reach more than 74 million tons in 2030 [11]. Electronics also contribute to a significant environmental threat, as e-waste is one of the primary sources of toxic materials and is often improperly handled [5].

Malaysia is an emerging country at a higher risk due to poor infrastructure and recycling practices. Traditional disposal via landfilling increases environmental risks, as toxic substances leach into soil and water [5]. Despite the growth, Malaysia has few household e-waste take-back programs or recycling facilities. This has contributed to brick-making activities being located near quarry sites. Coupled with the widespread lack of recycling infrastructure and premises, such as licensed recovery facilities (only two were found in Perak in 2018 at the time of the study), the recycling of debris was further impeded [13]. Additionally, the environmental damage has accelerated and caused severe harm to the surroundings, which in turn is affecting the economy of the state. As the scarcity of space increases, the cost of alternative space is nearly impossible due to the high risks involved [14].

Key factors influencing the recycling rates of e-waste in households include facility infrastructure, incentives, and government regulations. Although awareness has been strongly related to sustainable recycling behavior, such an element is most affected by the incentives and regulations put in place [1]. On the other hand, a lack of awareness usually results in an indifferent attitude or incorrect disposal behaviors. Furthermore, distance and access to a recycling facility greatly affect recycling rates, demonstrating the need for more conveniently located and accessible recycling facilities [12]. Consumer behavior surrounding informal recycling also suggests formalizing financial incentives to improve recycling rates, as green practices rewarded by informal recycling become adopted by consumers [15]. Implementing governmental policy, especially extended producer responsibility (EPR) laws, is critical in structuring successful recycling pathways [16]. Digitalization initiatives, such as those explored within logistics management, also imply the capability of technology to improve waste management and recycling processes [17].

The results from the survey in Ipoh demonstrate strong empirical relationships between these factors and e-waste recycling rates. The most important factors, appearing with relatively high prevalence, included public awareness, government policy, the availability of recycling facilities, and economic incentives. More specifically, 61.7 percent of those polled said they would be willing to recycle more if they had better information. On the other hand, 46.6 percent viewed governmental efforts as inadequate, indicating unanswered policy questions and that greater regulation and engagement are needed. Survey respondents also identified facility access as a key barrier, citing that 81 percent of respondents would recycle if facilities were readily accessible. The least significant factor identified was incentives, indicating that financial incentives play a minimal role among households in Malaysia.

Concisely, emerging strategies to better promote e-waste recycling include, but are not limited to, creating/increasing interactive yet reachable recycling bins, electronically produced educational campaigns, an electronic bonus card scheme (EBCS) system, and using social pressures from the public to shape recycling behavior. Prospective studies should also widen their focus to explore e-waste other than smartphones and response bias regarding demographic variables, including age, gender, location, and education.

Ultimately, this research elucidates the critical elements of awareness, government policy, infrastructure, incentives, and digitalization that shape e-waste recycling behavior within Malaysian households, guiding policymakers and stakeholders in developing effective, targeted strategies to address the e-waste crisis and advance environmental sustainability. As such, they identified and formulated five hypotheses in response to the research focus:

Hypothesis 1

$H_{1:}$ Facilities have a significant effect on improving the e-waste recycling rate.

Hypothesis 2

$H_{1:}$ Incentives have significant effects on improving the recycling rate of e-waste.

Hypothesis 3

$H_{1:}$ Government policy has a significant effect on improving the e-waste recycling rate.

Hypothesis 4

$H_{4:}$ Facilities have significance if incentives are involved in improving e-waste recycling rates

Hypothesis 5

$H_{5:}$ Government policy is significant if incentives are involved in improving the e-waste recycling rate

3. Methodology

Regarding the study, the survey was employed as a research method for data collection. Questionnaires were distributed to the targeted respondents (N=384) in Ipoh through both online (Google Forms) and offline (hardcopy) methods. Respondents were selected using a simple random sampling technique, where each individual within a household in a specific age group had an equal chance of being chosen as a sample. The questionnaires were structured into three sections: Section A covered demographic profiles, Section B included questions on electronics usage and independent variables influencing the current e-waste recycling rate (Facilities, Awareness, Incentives, and Government Policy), and Section C contained questions related to the e-waste recycling rate. The primary focus was on examining the relationship between facilities, awareness, incentives, and government policy in improving the e-waste recycling rate.

Sections B and C's statements were analyzed using a 5-point Likert scale. The five scales were used to determine the degree of agreement or disagreement with the statements, with score one representing strongly disagree, (2) disagree, (3) neither agree nor disagree, (4) agree, and (5) strongly agree. After gathering feedback from the respondents, the obtained data was entered into the Partial Least Squares SEM software for further analysis.

4. Findings

4.1. Exploratory Factor Analysis

Table 1 highlights the factor loading of each item used to measure the respective variables in this research. Items with loadings (>0.5) for the same factors were chosen to represent each variable. All factor loadings from the table are above 0.5, indicating good item reliability. Cronbach's Alpha reveals a value above 0.7, indicating high internal consistency of the scale used. Hence, no items are being deleted, and the condition is met and confirmed in this study. Composite reliability is also above 0.7, demonstrating that all the constructs have good internal consistency.[18]. All constructs have an average variance extracted (AVE) higher than the threshold of 0.5, which is considered acceptable [19], confirming the convergent validity of all the constructs (see Table 2).

Table 1.
Reliability analysis of each factor.

Code	Variables	Cronbach Alpha	Factor Loadings
DVEW1	Increase E-Waste Recycling Rate	0.952	0.927
DVEW2			0.927
DVEW3			0.908
DVEW4			0.906
DVEW5			0.915
IV1GP1	Government Policy	0.959	0.924
IV1GP2			0.921
IV1GP3			0.933
IV1GP4			0.925
IV1GP5			0.934
IV2F1	Facilities	0.965	0.916
IV2F2			0.938
IV2F3			0.947
IV2F4			0.944
IV2F5			0.936
IV3I1	Incentives	0.957	0.924
IV3I2			0.922
IV3I3			0.922
IV3I4			0.930
IV3I5			0.922

Table 2.
Construct Validity.

	Composite reliability	Average variance extracted (AVE)
E-waste Recycling Rate	0.952	0.84
Government Policy	0.962	0.86
Facilities	0.965	0.876
Incentives	0.957	0.854

Discriminant validity explains the differences between each construct and other constructs [18]. It can be achieved by establishing a low correlation between all measures of the variables and measures of another construct. The square root of AVE is compared against other constructs to better understand discriminant validity. The results can be seen in Table 3 below. Based on Henseler et al. [20], the cut-off points for establishing discriminant validity between two constructs are 0.90. The results show that all the HTMT ratios are below 0.90, indicating no discriminant validity problem in this study.

Table 3.
HTMT Results.

	EW	GP	F	I
EW				
GP	0.652			
F	0.789	0.663		
I	0.707	0.321	0.489	

4.2. Structural Model

The structural model explains the connection between the constructs that were hypothesized in this study. The structural model results from the PLS output can be seen in Figure 1 and Table 4. Government policy (GP), facilities (F), and incentives (I) have a significant direct relationship with the increasing rate of e-waste adoption (EW). Table 4 reveals the direct relationship output from Smart PLS.

In this research, Incentive (I) has been discussed and hypothesized as a moderating effect. Based on the indirect effect output results in Table 4, Incentives moderate the relationship between government policy and an increase in the e-waste adoption rate. Meanwhile, the relationship between facilities and an increase in the e-waste adoption rate indicates that incentives do not moderate that relationship.

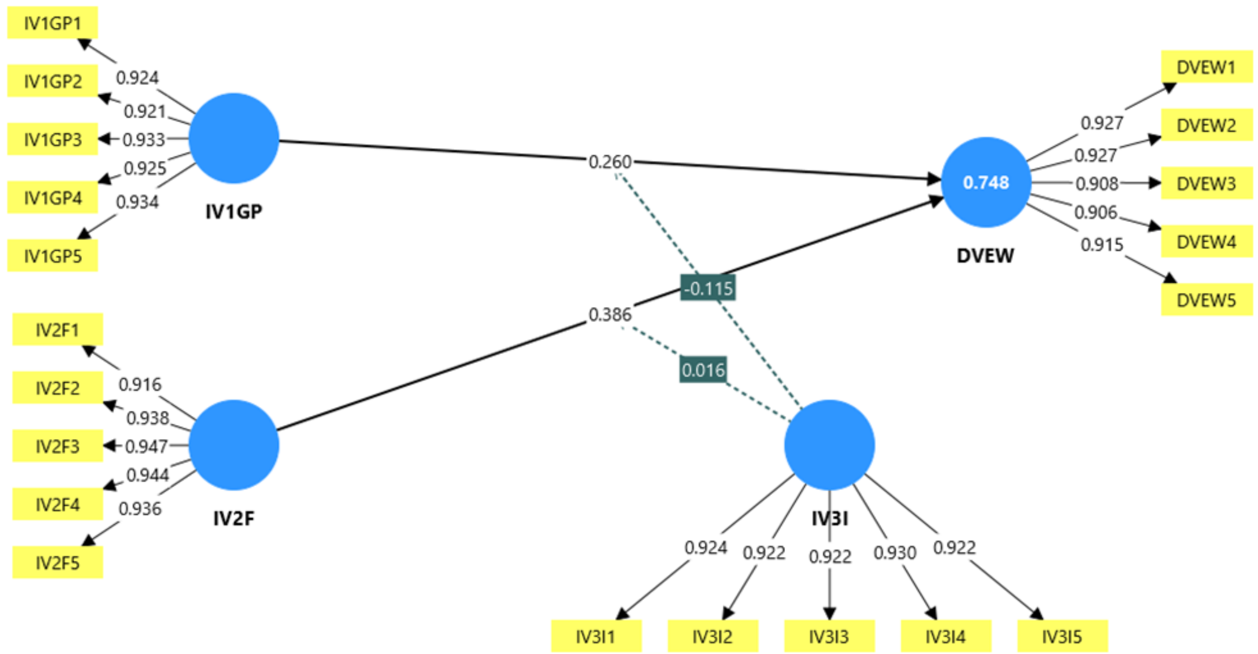

Figure 1.
Structural Model.

Table 4.
Direct and Indirect Effects.

	T statistics	**P values**	**Results**
GP -> EW	5.992	0	Supported
F -> EW	8.787	0	Supported
I -> EW	12.131	0	Supported
	T statistics	P values	Results
I x GP -> EW	2.729	0.006	Supported
I x F -> EW	0.402	0.688	Not Supported

5. Discussion and Conclusion

This research primarily concentrated on identifying factors affecting households' low rate of e-waste recycling. Based on this study, all the factors, facilities, government policy, and the moderator variable incentive have proven to significantly improve the e-waste recycling rate among households. These findings showed that 324 out of 384 respondents agreed that they recycle because they want to protect and conserve the environment. Additionally, 61.7% of the respondents expressed their willingness to recycle more often if they received more information on e-waste recycling. Next, government policy was the second most significant factor in improving the e-waste recycling rate. According to feedback from respondents, 46.6% agreed that the government has not prioritized e-waste recycling, and more than 60% perceived the current low e-waste recycling rate as a consequence of a lack of related government policy. Furthermore, over half of the respondents perceived the inconvenience of recycling facilities as an obstacle to participating in recycling practices. This is supported by the fact that 81% of these respondents indicated a higher likelihood to participate in e-waste recycling if the facilities were more convenient. Incentives, as the least significant factor in motivating respondents to participate in e-waste recycling, are likely less influential because the Malaysian community generally is not attracted to recycling for cash rewards or the market value of recyclable goods, as 59.4% of respondents agreed or strongly agreed that incentives are not the main driving factor for their recycling behavior.

To reverse the e-waste recycling scenario, several proposed recommendations should be considered. Firstly, interactive e-waste recycling bins, such as ‘We Recycle,’ are suggested to be located near households [21]. The bin could cultivate a positive attitude and enhance the perception that recycling could be enjoyable by providing attractive feedback to users. Next, electronic producers should create promotional videos to educate consumers regarding e-waste on their official webpages. Electronic producers’ participation, particularly those of high influence, is expected to boost the e-waste recycling rate by maximizing consumers’ e-waste knowledge exposure and awareness. Furthermore, the Electronic Bonus Card System (EBCS) for e-waste collection should be implemented in specialized trading networks selling EEE products. In contrast, an e-waste collection service at specified collection points is offered [15]. This system enables households to return their e-waste, and, in exchange, they receive financial incentives such as bonuses or vouchers. Moreover, social pressure has a greater influence on enhancing the e-waste recycling rate, with friends, families, and social groups encouraged to participate in e-waste recycling programs to influence those around them. The tendency of people to follow the crowd, creating domino effects, is anticipated to bring about the desired increase in the e-waste recycling rate.

Nevertheless, we observed some limitations in the study, such as the focus area of e-waste being narrowed to only small IT and telecommunication equipment; thus, we recommend future research to explore household disposal or recycling of other e-waste categories, including large equipment. Additionally, future research should target and study respondents from different socioeconomic classes or specific demographic backgrounds, such as purchasing power, which would help eliminate biased responses.

In summary, this study aimed to provide a deeper understanding of the significant relationship between these factors (facilities, incentives, and government policy) and the improvement of household e-waste recycling rates. In the context of the household e-waste issue, Ipoh, Perak, was selected as the targeted area for this study, which is expected to reflect other states in Malaysia despite variations in the quantity of e-waste produced by households. Therefore, it is crucial to consider these factors, facilities, incentives, and government policy in addressing the large volume of e-waste, which has been found to be significant based on this research. Consequently, the increasing trend of household e-waste recycling should help minimize the harmful effects of e-waste and promote sustainability.

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